Remote Airport Traffic Control Center (RaiCe)

Project RAiCe (2008 – 2012)
Final Presentation and Workshop
Extended Abstracts

DLR ID IB-112-2013/20
Classification A/I

Institut für Flugführung
Director: Prof. Dr. Dirk Kügler

Document Control Information

Responsible Project Manager / Department Head:	Dr. Norbert Fürstenau
Responsible Author/ Editor:	Norbert Fürstenau
Additional Author(s):	Michael Ellinger (Frequentis) Stephen R. Ellis (NASA-Ames) Ines Ernst Maik Friedrich Winfried Halle Jörn Jakobi Göran Lindquist (LFV) Sandro Lorenz Monika Mittendorf Christoph Möhlenbrink Anne Papenfuß Michael Rudolph Sebastian Schier Markus Schmidt Jürgen Wohlfeil
Project / Research Task:	RAiCe
Classification:	A/I (open document)
Filename:	IB_RAiCe_FinalWS_Abstracts_v12013-04-19.docx
Release:	0.01
Save date:	2013-05-15
Total Pages:	47

Release Note:

Document is released in accordance to Document Control Sheet:

Change Log

Release	Date	Changed Pages or Chapters	Comments
0.01	2013-04-17	All. New structure for DLR-Internal Report.	Transfer from distributed booklet of workshop papers (30.11.2012) with corrections and extensions
0.02	2013-05-15	Adding of authors CVs	Deadline for additional input / corrections from authors

Content

Zusammenfassung (Executive Summary)

Der vorliegende Bericht enthält die überarbeiteten Kurzfassungen der Beiträge auf dem Abschlussworkshop des DLR-Projekts RaiCe (Remote Airport Traffic Control Center), 2008 – 2012), der unter internationaler Beteiligung am 30.11.2012 in Braunschweig stattfand.

Der RAiCe workshop war eine Veranstaltung in direktem Anschluß an die zweiten „SESAR Innovation Days“ und dort angekündigt (SID 2013, 27.-29.11.2012, Braunschweig), in Nachfolge von SID 2011 in Toulouse. Einer der RAiCe-Beiträge betreffend die Validierungsergebnisse wurde auf der SID-Veranstaltung präsentiert und ist sowohl in den SID-Proceedings als auch in diesem Bericht enthalten.

Ergänzend zur Sammlung der Abstracts wurde ein einleitender Abschnitt und im Anhang neben einer Liste allgemeiner Referenzen eine Liste der Publikationen der Remote Tower Arbeitsgruppe aufgenommen (Zeitraum (2002 – 2012). Ebenso findet sich dort die Teilnehmerliste des workshops.

1 Scope of Document

The present report contains the extended and revised version of the abstracts collection of the presentations given at the final international workshop of the DLR-project RAiCe (Remote Airport traffic Control Center, 2008 - 2012), held on November 30 2012 in Braunschweig. The RaiCe presentations are complemented by two external contributions,from the Swedish ANSP LFV and company Frequentis, representing the industrial perspective on Remote Tower research and development.

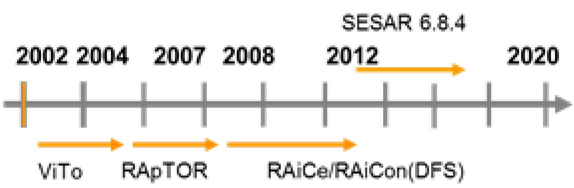
The RaiCe workshop was a satellite event of the Second SESAR Innovation Days (SID 2012, Nov. 27-29) which was held in Braunschweig, following the first one in Toulouse 2011. One of the RaiCe validation results papers was presented at SID2012 and is also included in the present report for completeness, besides inclusion in the SID2012 proceedings.

In addition to the collection of extended abstracts and an introduction, besides some general references a list of the publications of the DLR Remote Tower Group (time frame 2002 – 2012) is provided. A list of the workshop participants is added as part of the Appendix.

2 Introduction

Since about ten years an increasing interest is observed worldwide in remote control of small airports. It is connected with the paradigm change in air transportation due to the growth of low cost carriers and the corresponding increased usage of small airports which nevertheless require controlled air-space provided by ANSP's. Cost constraints require new ideas and concepts to meet these require-ments, and the control of one or more small airports from a remote location without direct visual sur-veillance from a local tower is one of these visions. A control center for remote airport/runway/apron surveillance (Remote Tower Operation, RTO) could also provide a significant contribution to the "Clus-tered Runway" or "Runway Network" ideas formulated within the SESAR target concept D3, with the goal of increasing ATM system efficiency.

Realizing this situation the DLR initialized in 2002 the Virtual Tower (ViTo) concept study (2002 – 2004, winner of the first DLR Visionary Projects Competition. It addressed questions of using Aug-mented Vision and Virtual Reality (VR) in the control tower for supporting controllers decision making, and replacing the conventional tower building by a control center without direct visual surveillance as long-term goal. The origin of the Virtual Tower idea can be traced back to early contacts and visits at the Advanced Displays Lab (Steve Ellis) at NASA Ames with focus on Augmented Reality/Enhanced Vision in the tower ([1][2], see general references) which eventually led to a research cooperation with NASA-Ames [38][40][47].
The initial ViTo- study was followed by the project RApTOr (Remote Airport Tower Operation research, 2005 - 2007) which aimed at the intermediate step of remote control of small airports. Based on the RapTOr results the goal of realizing a RTO-center demonstrator for verification of long distance high resolution video transmission, validation of essential functions of single small airport RTO, and investi-gation of multiple airport surveillance from a RTO-center was pursued within the follow-up project RaiCe, the topic of the present workshop. For the validation trials under RAiCe WP 4 a close coopera-tion between DLR and DFS was initialized in 2010 (Remote Airport Cooperation, RAiCon).
Within about the same time frame Company Saab together with the Swedish ANSP LFV started activi-ties towards centralized remote control of Swedish airports under the headline "Remotely Operated Tower (ROT)". A demonstrator facility was realized in Malmö for initial verification and validation of remote control of a distant airport. This development was continued within the 6th Framework EC pro-ject ART (Advanced Remote Tower). Since 2010 under the Single European Sky SESAR Joint Under-taking, Project 6.9.3, the NORACON consortium with Saab, LFV, and other partners continued the Swedish RTO development and validation. Within SESAR project 6.8.4 the German ANSP DFS to-gether with DLR started a complimentary validation project in 2012 which continues work package 4 (field tests and initial validation) of DLR project RAiCe. Results and analysis of the DLR-DFS validation trials at Erfurt airport are part of the initial SESAR 6.8.4 validation phase and complement the NORACON trials. An overview on the DLR Remote Tower activities is given in the following sketch:



Several requirements for "Future ATM Concepts for the Provision of Aerodrome Control Service" have been formulated by the International Federation of Air Traffic Controllers Associations (IFATCA), such as:

The controller shall be provided with at least the same level of surveillance as currently provided by visual observation

Controllers shall be involved in the development of aerodrome control service concepts

In a recent paper Brinton & Atkins of Mosaic ATM Company (Brinton & Atkins (2006) *Remote Airport Traffic Services Concept,* Proc. I-CNS Conf., Baltimore 5/2006) concluded that

"*Requirements for RTO are beyond capabilities of today's electronic airport surveillance systems"*, however:

"a combination of electronic surveillance, optical surveillance and advanced decision support tools may satisfy the Remote Airport Traffic Service requirements".

Citing [38]: "While many current towers on ASMGCS-equipped airports, even some at busy airports like London-Heathrow, can continue to operate totally without controllers ever seeing controlled aircraft under contingency conditions, it is clear from controller interviews that usually numerous out-the-window visual features are used for control purposes. In fact, these visual features go beyond those required for aircraft detection, recognition, and identification. Potentially important additional visual features identified by controllers in interviews involve subtle aircraft motion (for further references see "RAiCe publication list)." The importance of direct visual surveillance for creation of a complete situational awareness, resolution of ambiguities in complex situations, and decision making with minimized error probability requires more basic investigations and computational modeling of perception problems, and advanced psychophysical methods and data analysis, e.g. eye tracking and detection theory.

At this workshop essential results of the four main workpackages of the DLR project RAiCe are presented (Scenarios & work analysis, algorithms (for image processing) & simulation, experimental system & demonstrator,field testing & shadow mode trials) including live demonstrations of the experimental videopanorama system at the DFS-controlled Erfurt Airport, and demonstrations of the RTO simulation facility. In addition the Swedish approach to RTO/ROT and an industrial prototype solution from company Frequentis/Austria will be presented.

Following a RAiCe-project overview by Norbert Fürstenau, work analysis and requirements for RTC will be presented by Anne Papenfuß. She was also the responsible project manager for a detailed multiple airport workload study including simulation trials (DFS contract).

The results of the previous RapTOr project demonstrated the technical feasibility of the visual surveillance component of RTO systems, realized by high resolution live video reconstruction of the out of the tower view with minimized delay. Besides radio communication and approach radar the latter is often the controllers only information source for the traffic situation on small airports. Based on the detailed requirement analysis a new high-resolution HD-format panorama camera and Display system was constructed at the DFS controlled airport Erfurt for validation under passive shadow-mode conditions from an RTO work position with a standard DFS operator console. It served for direct comparison of the RTO workplace with the conventional tower condition. Markus Schmidt as chief engineer and leader of the DLR-DFS cooperation RAiCon (2010-2012) will report on this new experimental RTO-system.

The RAiCe software development with improved performance as compared to the original RApTOr system at Braunschweig airport will be presented by Michael Rudolph. A live RTO-live demo with the Erfurt airport traffic situation will complement these experimental aspects.
An important part of the RAiCe project is the new RTC simulation facility which served for serveral simulation campaigns addressing high fidelity human-in-the-loop simulations with single RTO and multiple RTO (RTC) scenarios as well as specific questions like video frame rate requirements using part-task simulations. Sebastian Schier and Sandro Lorenz will present a demonstration of the fast time and real time simulation facilities.

As an example for a highly ambitious simulation campaign Christoph Möhlenbrink will present results of a workload study based on human-in-the-loop simulations with domain experts (DFS tower controllers). In a simulator study a RTC work environment was realized for controlling two regional airports. In a three-factor experimental design different work organizations and their effects on workload were investigated. In addition, expert observers identified safety critical ATC situations.

Another simulation experiment showed the potential of deriving technical requirement data from part task simulations involving dual choice decision tasks. This talk was presented by N. Fürstenau during the SESAR Innovation days, immediately preceding the RAiCe workshop. It addresses derivation of video frame rate requirements from dynamic scenarios using psychophysical detection theory and Bayes inference. These methods are presently also used for deriving objective RTO performance criteria from decision data of the validation trials (accepted for publication [48], and see below: contribution by M. Friedrich)

The digital live reconstruction of the tower out-of-windows view offers a large potential for automation and controller decision support, e.g. by movement detection (image processing), data fusion (e.g. video and radar or GPS-ADSB) and PTZ-camera tracking. A working example of this kind was demonstrated already within the previous RTO-project. The challenging task is to turn these options into reliable and operationally useful tools. W. Halle and I.Ernst (DLR branch for Optical Sensing Systems) present results of their work on problems and achievements within this area of research.

The RAiCe validation experiments were prepared and realized within the DLR-DFS cooperation project RAiCon. The DLR-test aircraft was used to perform reproducible operational scenarios and aircraft maneuvers during aerodrome circling within the Erfurt-airport control zone. This allowed for direct comparison of controller performance under tower and remote conditions and for quantitative data analysis using subjective and objective metrics. Maik Friedrich was in charge of planning and preparing the experiments including data collection and organizing the evaluation, and he presents initial analysis of the experimental results, in partial fulfillment of a deliverable for SESAR project 6.8.4.

Two external contributions complement the RAiCe project topics. Göran Lindquist (LFV) presents the Swedish approach to ROT (Remotely Operated Tower), realized with company Saab-Sensis. This development with technology comparable to the DLR approach run in parallel to the DLR activities and has undergone already several validation trials, partly under the European SESAR joint undertaking (project 6.9.3). Michael Ellinger of company Frequentis/Austria will present the industrial development “smartVISION”. His focus will be on advancements in the automation aspects (detection and tracking).

References (see also the “General References” and “Publications” sections 15.2, 15.3 in the Annex):

Fürstenau, N., Schmidt, M., Rudolph, M., Möhlenbrink, C., Halle, W.: Augmented vision videopanorama system for remote airport tower operation, Proc. ICAS 2008, 26th Int. Congress of the Aeronautical Sciences.I. Grant (Ed.), Anchorage, Sept. 14-19 2008, ISBN 0-9533991-9-2

Hannon, D., Lee, J. T, . Geyer, M., Sheridan, T., Francis, M., Woods, S., Malonson, M. (2008): “Feasibility evaluation of a staffed virtual tower". The Journal of Air Traffic Control, Winter 2008, 27-39.

Brinton & Atkins (2006): *Remote Airport Traffic Services Concept,* Proceedings, I-CNS Conf., Baltimore 5/2006

Ellis, S. R., Fürstenau, N., and Mittendorf M.(2011): *Determination of Frame Rate Requirements of Video-panorama-based Virtual Towers using Visual Discrimination of Landing Aircraft Deceleration during simulated Aircraft Landing.* Fortschritt-Berichte VDI, Reihe 22, No. 33, pp.519-524

Watson, A.B, Ramirez, C.V., Salud, E., (2009): “Predicting visibility of aircraft”, PLoS ONE. 4(5): e5594. Published online 2009 May 20. doi: 10.1371/journal.pone.0005594

2.1 Definitions

As results of the discussion of the first Remote Tower (RapTOr) workshop in 2006 the following definitions were found (modified):

Virtual Tower (ViTo):
Replacement of conventional Tower out-of-windows view by tower-less control center with high quality real time videopanorama reconstruction should provide for only moderately changed work conditions & training procedures. Not necessarily a 3D reconstruction. Sufficient electronic surveillance data for data fusion with video and IR surveillance could be a basis for a synthetic vision Virtual Reality display system with advanced functions like arbitrary perspective and distance selection.

Augmented TWR Vision (ATV):
Superimposition of 3D or 2D Data / Symbology on external world
a) Visual see through: superimposition of Data / graphics via transparent display (e.g. head mounted retinal scanning, head-up holographic projection)
b) Video see through: superimposition of data / graphics on real time video (e.g. Approach Radar, GPS/ADS-B, with geo-coordinate reference)

Remote Tower Operation / Remotely operated Tower (RTO/ROT):
Control of a small airport or apron areas from a remote location: RTO workplace located in distant tower of a larger airport or in a Remote Tower Center

Remote Tower Center (RTC)
RTO / ROT Center for remote control of several several airports. Option for single operator control under sufficiently low traffic and with the help of decision support systems.

2.2 List of goals, technical aspects and achievements

During the first RapTOr workshop at DLR / Braunschweig in 2006 the discussion concluded the following fundamental aspects:

General RTO Goals

- Keep work processes as close as possible to established ones
- Keeping human in the loop
- Investigate importance of visual cues: Visual cues database
- Feasbility of RTO with regard to cost reduction (small airports)
- Set up of RTO simulation environment
- Verification & validations: performance changes of hum. Operator with RTO?
- Safety analysis / Regulatory aspects (ICAO)

Technical issues

- Cameras + projection / displays with sufficient dynamic range & resolution
- Communication links: bandwidth no issue but cost?
- Techniques for keeping human in the loop: RTO workplace design require-ments
- Evaluate other sensors for integration (ADS-B, multilateration,….

Achievements

- Requirements from TWR work analysis
- RTO/RTC simulation system at DLR/Braunschweig
- Experimental systems in Braunschweig (DLR), Erfurt, and Malmö/Sweden
- Shadow mode testing in Sweden and Germany

Organisational issue

- Establish network for info exchange and standardisation: -> SESAR Valida-tion Projects 6.9.3 (NORACON), 6.9.4 (DFS-DLR, since 2012)

RAiCe Goals

- Derive requirements based on work and task analysis and simulations

- Set up of RTO/RTC simulation environment for two-airport control
- Define RTC scenarios and work environments based on simulations
- Investigate and develop appropriate theoretical and methodological back-ground
- Development of advanced videopanorama system base on RApTOr system
- Investigate possibilities of movement detection, PTZ tracking, and Aug-mented Vision
- Setup and Investigate remote high bandwidth connection with remote airport
- Build RTC demonstrator at distant airport for validation trials
- Prepare and perform passive shadow mode tests under quasi operational conditions

RAiCe Technical issues

- Improved HD camera and panorama display system
- Bayer conversion, compression, and image processing
- Design and test of long distance broadband video transmission. Delay times and stability issues
- Augmented vision, data fusion, object tracking (PTZ-camera control)
- Simulation facilities for RTO fast-time and human-in-the-loop simulations
- RTO-demonstrator for shadow mode tests under quasi operational condi-tions.

RAiCe Achievements

- RTO requirements analysis based on domain experts interviews and two-airport scenarios
- Several Fast-time, human-in-the-loop and part task RTO- and RTC-simulation campaigns
- Use of advanced measurement (e.g.eye tracking) and data analysis tech-niques
- establishment of theory based data analysis for objective metrics (SDT) and (cognitive) modeling approaches
- New HD-technology cameras and panorama display system
- 50 Mbit connection between remote (Erfurt) camera system and 200° x 60° wide angle HD-technology videopanorama
- Passive shadow mode tests at Erfurt airport with reproducible flight scenarios using DLR test aircraft for aerodrome circling and maneuver detection tasks. Quantification by subjective and objective metrics and direct comparison tower vs. RTO

RAiCe Organisational issues / Cooperations

- DLR-DFS Cooperation RAiCon (2010-2012: -> Validation experiments at Erfurt airport
- SESAR-JU (2012-2015): DLR-DFS cooperation - RTC Validation Project 6.8.4, complementing Project 6.9.3 (NORACON)

2.3 Program

Friday, November 30 2012		
	08:30	*Registration (Hermann-Blenk Lecture Hall)*
	09:15	Welcome & Introduction to Workshop (D. Kügler)
	09:30	Project RAiCe: Overview (N. Fürstenau)
	09:55	Work Aanalysis for Remote Tower Center Control (A.Papenfuss)
	10:20	RAiCe Experimental System and DLR-DFS Cooperation „RAICON“ (M. Schmidt)
	10:40	RTO-Software System (M. Rudolph)
	11:00	*Break (walk to building 117, Inst. of Flight Guidance, ground level, Tower Simu-lator)*
	11:20	Fast Time Simulations and RTC – Simulation Environment (S. Schier, S. Lorenz)
	11:50	Live-Demonstration (M.Schmidt, M.Rudolph)
	12:20	*Lunch Break (Hermann-Blenk Lecture Hall - Foyer)*
	13:10	The Role of Workload for Work Organization in a Remote Tower Control Center (C. Möhlenbrink)
	13:35	Image Processing and Object-Tracking (W. Halle)
	14:00	The Swedish Perspective on Remote Tower (G. Lindquist, LFV/Sweden)
	14:25	*Break*
	14:45	smartVISION – A new approach for video based surveillance for ATC (M. Ellinger, Frequentis/Austria)
	15:10	DLR-DFS Cooperation „RAiCon“: Validation Experiments & Results (M. Friedrich)
	15:35	Outlook, Perspectives, Discussion (N. Fürstenau)
	16:00	End of Workshop

3 Project RAiCe: Overview

Norbert Fürstenau

3.1 Remote Tower Operation

Remote Tower Operation (RTO) describes the goal of remote control of small airports and of movement areas of large airports which are not directly visible from the control tower. Project RAiCe continued the DLR-Project RapTOr (2005 – 2008) and the initial Virtual Tower study ViTo (2002 - 2004). Within RAiCe an improved HD-technology videopanorama was developed and initial validation experiments performed together with DFS under more realistic passive shadow-mode conditions. Another goal was the setup and testing of the long-distance connection between a DFS-controlled remote airport and the experimental Remote Tower Center (RTC) of the DLR-Institute of Flight Guidance at Braunschweig Airport. Results of tower work and task analyses and simulation experiments showed the importance of the direct far view out of the tower windows and of visual cues for establishing the controllers' situation awareness under present day work conditions. This finding provided the initial motivation for developing the digital high resolution augmented vision video panorama in combination with a pan-tilt zoom camera (PTZ) as main component of the RTO Human Machine Interface (HMI) that replaces the direct out-of-windows view of the conventional control tower.
Within the previous DLR project RapTOr (2005-2007) a first experimental RTO-system for initial field testing was realized at the Braunschweig research airport.

Figure 1: Braunschweig Airport with main runway in east–west direction. Red lines indicate camera segments of initial 180° high resolution (UXGA) video panorama system, operating 2004-2012; red circle: camera location; yellow lines: fiber-optic high speed data network, thick line indicating 600 m Gbit link for video transmission.

A PC-cluster for image processing and compression at the camera position allows for storing panorama and zoom data (roughly 20 GByte of data per hour). This feature provides the possibility of complete panorama replay. The live 180°-video panorama of the initial system with synchronized video stream from four high resolution (UXGA) cameras and the remotely controlled PTZ-camera were displayed on five high resolution monitors. Interaction of the operator with the panorama system (cameras, weather station, stereo microphone) is performed via pen touch-input display. Field tests with expert and non-expert observers proved the visual resolution to match the theoretically expected value of ca. 1/30° (pixel resolution) if viewing conditions provide sufficient object-background contrast. This resolution is about half as good as the diffraction limited value of the human eye (1 arc min).
Based on the experience gained with the original system with 3 / 4 – camera and display format and UXGA resolution an improved (200°-) video-panorama system with 16 / 9 HD-video standard was developed with increased vertical viewing angle (60°) in order to meet the operator requirements.
As core of the RTO HMI a high resolution video panorama system was set up at Brauschweig research airport as experimental environment for investigation of different technical and psychological aspects and for the development of a demonstrator. Figure 2 shows the panorama camera system consisting of four latest technology digital high resolution cameras (1600 x 1200 pixel, 14 bit dynamic range) as basic sensor system, with an additional remotely controlled pan-tilt zoom (PTZ) camera. The system operates at a frame rate of 25 Hz and provides a theoretical angular resolution of ca. 2 arcmin

which is half of that of the human eye (1 arcmin). The RTO operators console with five UXGA monitors for reconstructing a 180° panorama view and the zoom image, with pen touch input display as interaction device is shown in Figure 2(Right).

Figure 2: Left: RTO sensor system with five HD-format panorama cameras and pan-tilt zoom (PTZ) camera on top, mounted on roof platform of Erfurt-tower (height 41 m). (see contribution of Schmidt). Right: RTO videopanorama display system with five HD-format displays for 200° view. Setup at DLR RTC-Simulator facilities for live transmission from Erfurt airport (200 km, with 50 Mbit/s)

The touch input display allows for remote control of the PTZ camera via a virtual joystick or pointing at a target position in a miniature version of the panorama, refreshed with a reduced rate of 5 Hz. Alternatively automatic tracking based on object movement detection can be selected for the PTZ. Electronic flight strips and diverse communication and control buttons are optionally included for field testing (see section 3.5 and 8)..

3.2 Features Beyond Conventional Control Towers

The digitally reconstructed panoramic out-of-windows view allows for several automation features which are not available within the conventional control tower environment. Besides image processing based automatic movement detection (e.g. using optical flow and background subtraction algorithms), augmented vision is of particular interest: flight data or real-time aircraft position information obtained via (Mode-S) transponder from approach radar, from a multilateration system or from ADSB-GPS / Satellite navigation may be integrated at the display coordinate of the respective aircraft.
Under reduced visibility Augmented Tower Vision (ATV) feature allows for localizing the a/c near the correct geographical position. In addition contours of the movement areas may be superimposed on the reconstructed panorama for guiding the operator’s attention during darkness or reduced visibility. Position data, e.g. from movement detection and approach radar allow for automatic PTZ-positioning and aircraft tracking by means of the zoom camera. Some of these features were demonstrated already within the previous project RApTOr.

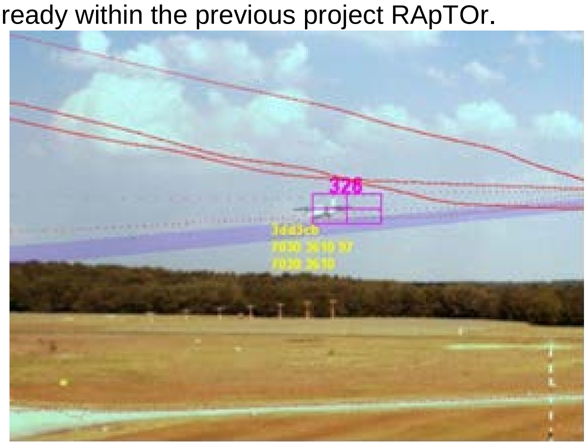


Figure 3: Augmented vision features with DLR test aircraft during approach: high-lighted 3°-glide path (violet), transponder code and multilateration position (yellow), A/C position from automatic movement

detection (numbered square), superimposed GPS trajectories (red: dense points represent distant movement, sparse points (high angular velocity) are nearby positions).
Digital data transmission between camera and display systems with 0.5 km distance in between is performed via a GBit ethernet, employing high perfor-mance PC clusters at camera and display loca-tions for compression and de-compression. A system for real time image processing with the uncom-pressed video data operates in parallel to the panorama system at 5 Hz. A full day of high resolution panorama data (0.5 to 1 TByte) is continuously stored into 2.5 TByte memory for replay.

3.3 Remote Tower Center

The RTO technology allows for realization of a Remote Tower Center (RTC) which combines several RTO workplaces for two or more remotely controlled airports from a central location, each airport equipped with its own high resolution camera system. Together with the live video stream all local airport data like approach radar, weather and radio communication with pilots are transmitted to the RTC workplace. RTC together with the RTO-specific auto-mation tools allows for new and more effi-cient control tower work organiza-tion. One aspect, e.g. is a common clearance delivery work position for several airports.

Figure 4: DLR Simulation Facility for Remote Tower Center Human-in-the-loop experiments (see con-tribution of A. Papenfuß, section 4)

3.4 RTC-Simulator and Validation of New Procedures

Validation of specific operational procedures, matched to the new RTC work environment requires a special RTO / RTC simulator in order to iteratively optimize the work situation within a process of par-ticipative design, i.e. with repeated feedback by tower controllers as domain experts. A high fidelity RTO/RTC simulator environment was realized as component of the DLR tower simulator. It provides the possibility to simulate the view from different (pano-rama) camera positions and to create repro-ducible traffic scenarios of different complexity. Within the DLR project RAiCe several simulation phases with controllers from different regional and international airports showed the principle feasabil-ity of remote control, even with a single operator responsible for two airports.

Figure 5: Dual airport control by single operator (see contribution of Möhlenbrink et al., section 11, [34][35][36][39][42])

3.5 Experiments under Real World Conditions: Passive Shadow Mode Tests

Within a cooperation between DLR and the german air navigation service provider DFS validation experiments under passive shadow mode conditions were performed at the local tower of the DFS-controlled remote low-traffic airport in Erfurt under more realistic operational conditions. For this purpose, besides the Braunschweig research airport the second regional airport was equipped with the improved HD-technology video panorama system. It also served for verifying the stable long distance (ca. 200 km) live videostream transmission to the RTC-testbed in Braunschweig which was realized with a 50 MBit/s connection.
Ressources for passive shadow mode tests under controlled conditions and reproducible scenarios were included in the initial RAiCe planning phase. The detailed validation plan for use of the DLR (DO 227) test aircraft D-CODE was developed during the last year of RAiCe and was based on aerodrome circling within the Erfurt control zone. Besides the typical operational procedures it included a series of events like altitude changes and gear-out/gear-in situations during approach for allowing the derivation of detectability indices with two-alternative decision tasks (yes/no answers) and analysis using signal detection detection theory (SDT). Within these experiments a direct comparison between tower out-of-windows observation and RTO condition was possible.

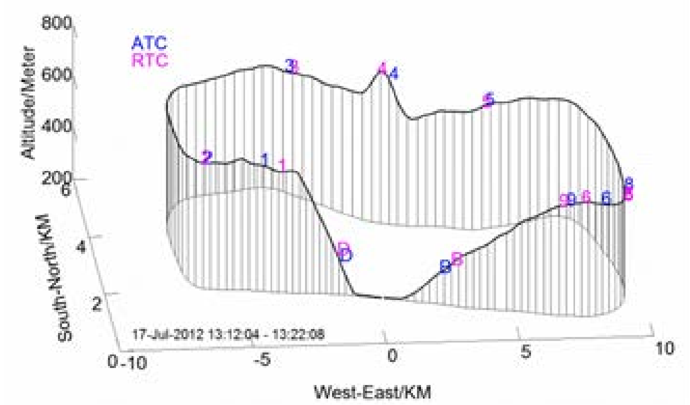


Figure 6: GPS-track of test aircraft during passive shadow mode experiments at DFS-controlled airport in Erfurt, July 2012 showing aerodrome traffic circuit with numbered events like bank angle (1) and altitude changes (4) indicating TWR/ATC and remote/RTC decision times (see contribution by Friedrich, this volume).

Examples of dual-choice decision task analysis using SDT for comparing tower-view discriminability with RTO panorama + PTZ work condition is shown in the following Figures for the case of gear-in / gear-out?, bank angle change, and lights off? observations (decision points B, 1, 9).

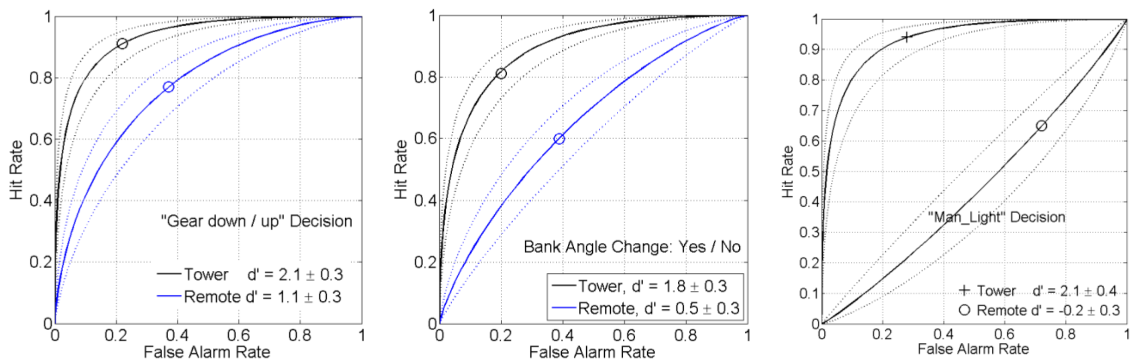


Figure 7: ROC (receiver operating characteristics) curves (± 1 σ) with (Hit, False Alarm)-data from response matrix for three different two-alternative decisions. Decision making under tower and RTO work condition (average for eight subjects, 7 observations each per event) depicting discriminability index d' of Tower observation to be a factor 2 – 3 larger than for RTO-CWP, and lights-off decision apparently not discriminable at all at the respective decision point with RTO (preliminary results, worst case analysis; for details see [48]).

For a discussion of d' and other detectability indices within the context of video frame rate requirements and field testing see Ellis et al. (2011) [38][40] and Fürstenau et.al.(2012, 2013)[47][48] in the publication list at the end, and Fürstenau et al. on page 32, this volume.

3.6 Videopanorama Contrast Aspects

The quality of the reconstructed videopanorama out-of-windows view as compared to the direct view out-of-tower windows is determined by the modulation transfer function (MTF) of the videopanorama system. The pixel resolution mentioned above is given by the Nyquist limit of the resolvable spacial frequency = 1/(2 pixelsize,), i.e. 2 pixel / light-dark cycle. Usually the camera / display contrast has decreased down to < 20 % of its maximum value so that the discriminability of small objects is expected well below this 1 pixel limit (i.e. minimum detectible object size is well above 1 pixel / bright line on dark background) as depicted in Figure 8 for the example of a HD-format color video camera with Beyer conversion:

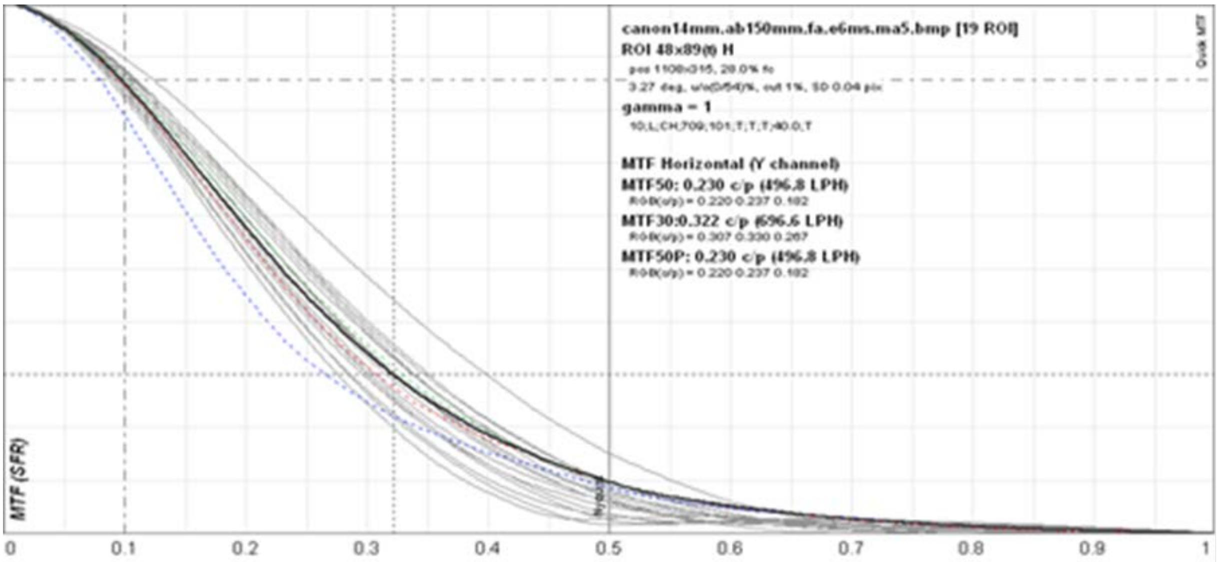


Figure 8: Measured Modulation Transfer Functions (MTF, abszissa:spatial frequency / cycles/pixel) of presently used HD-camera system . Obtained from line spread function and FFT at black-white edge; Canon lens, f = 14 mm [60].

The relevant angular resolution (human eye ca. 1 arcmin under optimum contrast conditions) of the camera depends on the lens focal width and may be obtained from the measured cycles/pixel value to first order via the Gaussian lens equation [60]. Of course the operator's object detectibility, besides observer-display distance and image (pixel) size also depends on the dynamic range (standard is 8 bit/pixel) and absolut contrast of the camera – display system, digital image preprocessing and the observers contrast sensitivity function, although the latter is not relevant when only the relative performance between different video-based systems is of interest.
The contrast (i.e. MTF) of color cameras can be assumed to be lower when measured with standard (black – white) calibration images as compared to that one of comparable black-white cameras. This is particularly true when removing the IR-filter from the b/w camera lens which is required for the color system. In that case black-white systems have the advantage of higher (average) quantum efficiency and semiconductor/CCD IR-sensitivity (up to ca 1 μm / 5% quantum efficiency). Besides this aspect significant sensitivity and contrast differences are reported between CCD and CMOS-camera technologies.
The usage of IR and thermal sensors as basic RTO-surveillance elements for improving detectability is proposed by one of the industrial developers (Frequentis, [9]). A possible superior performance of this approach for RTO of small airports, as compared to the standard (visible) videopanorama with PTZ, has still to be quantified, and like any other solution will depend on the fulfillment of many functions and requirements (besides detectability) derived from the TWR-operation work analysis, safety analysis, and the final acceptance by the domain experts.

4 Work Analysis for Remote Tower Center Control

Anne Papenfuß

The idea for a remote tower center (RTC) is that two or more airports with simple layout and little IFR traffic are controlled out of one center. Such a concept for a work environment was investigated within the project RAiCe. The concept is economically attractive for ANSPs, as a reduction of staffing costs is expected. Nevertheless, a remote tower center should be designed in a way that air traffic controllers are able to provide a safe and efficient flow of air traffic. Several possibilities of organizing tasks and responsibilities within this RTC are possible. In order to develop operational valid requirements for a remote tower center, it was one goal within the project RAiCe to understand the impact of work organization, workplace design and technical solutions on the work of the tower controllers.
A set of high-fidelity studies and laboratory studies were conducted. These studies provided empirical data on visual attention distribution, the mental traffic picture, workload as well as critical traffic situations in RTC operations.
In a first simulation campaign (01/2010, e.g. [34]) working at a conventional tower (tower simulator) was compared with working air traffic at the RTO workplace. A main focus was set on the relevance of information derived by the far view and the usefulness of information provided by additional information augmentation into the far view. The second simulation campaign (06/2010) set a focus into investigation of different work organizations within a remote tower center.
A central research question is, under which conditions one controller could control two airports at the same time and in which situations it is impossible to do so. In general, controlling two airports at the same time is a cognitive challenging task. Working a complex task in teams is one solution to meet demands regarding information acquisition, handling the dynamics of the environment and the coordination of several actions. An established work organization of tower control, consisting of executive and coordination con-troller, was applied to RTC operations and compared to a single operator, working two airports at the same time and two operators, each working one airport (control condition).
In order to understand the role of teamwork within RTC operations in detail, a case study of a traffic situation worked by the controller team was conducted, that was rated highly demanding within the single operator condition. Taskwork and teamwork processes within the controller team were identified. Explicitly, the team demonstrated a monitoring behavior of the performance of the other team member and adaptive task assignment to back-up the team member. Those behaviors enabled the team to work smoothly through the situation.

Figure 9: Simulation experiment with two-airport control.

Whilst team processes like cross-monitoring and backup can help to ensure safety within a RTC, a flexible assignment of tasks is a challenge as responsibilities always need to be clear. Overall, the results of the studies conducted in this work package, provide an empirical basis for future remote tower center concepts.

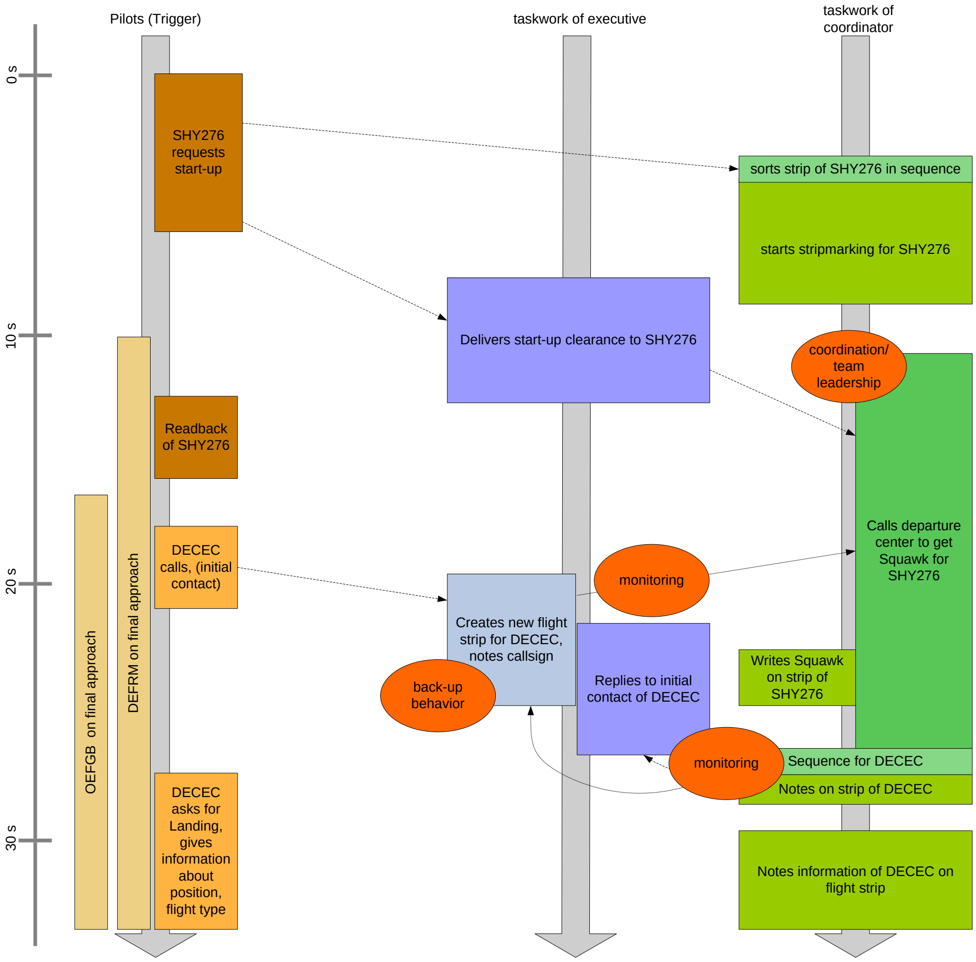


Figure 10: Timeflow of traffic and work of two cooperating controllers (executive and coordinator) [42]

5 RAiCe Experimental System and DLR-DFS Cooperation RAiCon

Markus Schmidt

One of the basic conditions of the RAiCe project is the implementation of an RTO-environment at a second airport. It serves for demonstrating the next level of hard and software solutions, and for pre-paring and executing the RTO-passive shadow mode test at this airport. For these aims we could en-list the German ANSP DFS for the Remote Airport Cooperation – RaiCon project which contains as subproject of RAiCe parts of the work packages wp. 3 and wp. 4.
The cooperation starts with the discussion and the breakdown of the re-quirement specifications with the DFS-experts. The analysis shows that it is impossible to consider all of these requirements in one affordable RTO design. This concerns the selection of numbers of cameras corresponding the number of displays for the panoramic view, the visual resolution and the vertical field of view.
Table 5.1 shows these options, with the different focuses.
The crucial factor for the selection of one of these options was the vertical FOV, according to the re-quirement controlling an altitude of 1000 ft. above the runway in the panoramic view.
So the RTO-system setup was defined with the following characteristics ac-cording to option 1:
- 5 industrial HD-cameras, 2/3”-CCD-technology, with f = 8 mm lenses
- single camera houses with heated and air blaster cleaned front glass
- 1 PanTiltZoom-camera (PTZ) with VGA-resolution, continuously hor-izontally rotatable and a tilt angle from -30° to 90°

	Option 1	**Option 2**	**Option 3**
Numbers of cameras / dis-plays	5	7	10
Vertical / hori-zontal FOV	66° / 190°	46° / 182°	34° / 190°
Resolution /	Ca. 2 arc mi-nute per pixel	Ca. 1,44 arc mi-nute per pixel	Ca. 1 arc minute per pixel
Main focus	High FOV	Medium FOV and resolution	High resolution
conclusions	Medium effort Medium reso-lution	Affordable but realistic	High effort Huge required space for the R-CWP

Table 1: Details of panoramic camera systems for RTO

Figure 10: Panorama camera and PTZ setup on top of the Erfurt Control Towershows the setup of the RTO-system mounted on the roof platform of the tower Erfurt. In addition the components for data transfer und power supply in the electronic cabinet and the air blast cleaner are well indicated.

The installation of the camera system took place after a complete assembling and tests at the DLR in Braunschweig. This concerns also an EMP-test of the complete camera and broadcasting system to prove successfully, that no radio emissions interfere with the DFS antenna equipment on the tower roof. It is also of particular importance that the design of the camera and broadcast system follows the DFS lightning protection and the power supply concept for DFS operating ATM-systems.

Another goal of the RAiCon cooperation was the concept, implementation and the start-up of a high bandwidth wide area network (WAN) between Brunswick and Erfurt for the data transfer of the video streams. This peer-to-peer connection is provided by T-Systems the DLR IT-SP including a bandwidth of 50 Mbit/sec, the router/switching devices at both points and an all-inclusive service.

Figure 11: Panorama camera and PTZ setup on top of the Erfurt Control Tower

This network is that it is decoupled from the DLR-domain as well as from the internal DFS-network so that data security at both sides of the connection is guaranteed. Figure 11 shows the concept of this permanent line between Bra and Erfurt.

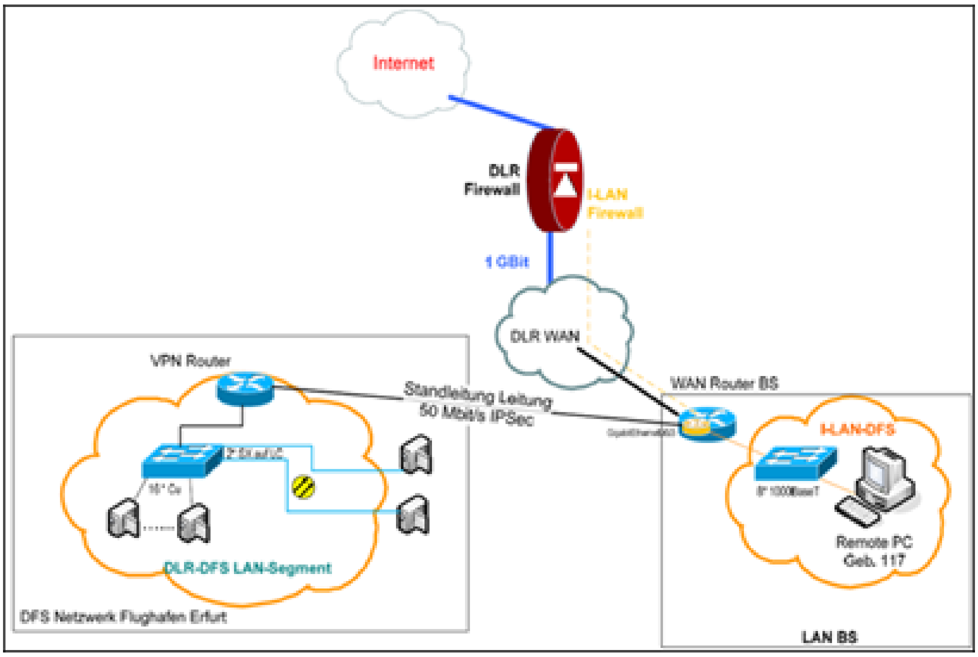


Figure 12: Concept of the WAN-connection between Braunschweig and Erfurt

During prototyping the camera sensor system the RAiCon team together with DFS-experts in the fields of ATC, engineering and safety discuss the concept and the design of the RTO controller working position (R-CWP). Within two design workshops the participants designed the R-CWP based on the re-quirement specifications and other conditions.

Figure 13: Design and implementation of the R-CWP

The result is a prototype of R-CWP on the basis of the latest DFS controller console with three information respectively input levels (see Figure 3).
The development and the installation of the R-CWP in a control room besides the tower building were made by DFS engineers. The R-CWP includes in addition to the panoramic view and the control and display monitor for the PTZ camera also the displays of the essential operational ATM systems.
A similar setup without these ATM systems is located in the TOWER-LAB at the DLR in Brunswick. It is used as development environment and particular to demonstrate the excellent data transmission performance of the WAN con-nection between Brunswick and Erfurt, i.e. the transmission of the video streams over several hundreds of kilometers.
Determinations of the delay times between an event in Erfurt and the display in the panoramic view in Brunswick have shown values near 300 msec, in which the data transfer requires ca. 20 msec and the remaining time is necessary for the video recording and processing at both sides of the connection.

The described camera sensor system together with the R-CWP in Erfurt is the technical basis for the validation tests in the context of SESAR WP 6.8.4. Details of these tests and an overview of the software specification are subjects of futher chapters within this volume.

6 RAiCe Software

Michael Rudolph

The RAiCe software is based on the software that was developed within the previous DLR project RapTOr. To be more flexible to use the software in other environments and with other hardware, it has been further developed.
The general data path of a video stream in the remote tower software is shown in figure 1.

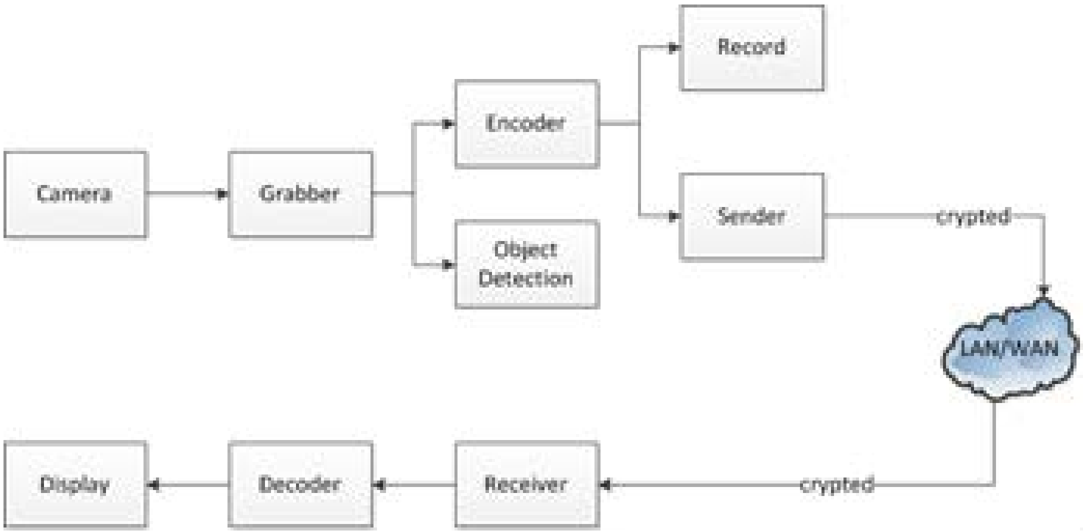


Figure 14: Data path of the video stream

The images are captured in the camera that transfers them to a grab-ber. In case of the most high quality industry cameras the images are in the Bayer color format. The grabber has to interpolate a RGB color image from the raw picture with an adequate algorithm to provide the best quality possible with preferably low delay. From the previous project we inherit the possibility to use any kind of grab-ber that delivers Microsoft DirectShow drivers and the support of a CameraLink grabber from Silicon Software. Within the project RAiCe we extend the support of usable grabbers to a GigE Vision grabber from Silicon Software and any kind of GigE Vision camera over a standard network interface card. In case of a network interface card the Bayer interpolation has to be done in software. We developed an algorithm that is fast and that allows to do some image processing without extra delay. In addition a network interface card is far cheaper than a special grabber card. Furthermore we have a grabber for simulated cameras in the DLR tower simulator, so we can use the same software in the real world and in the synthetic DLR simulation environment.
The output of the grabber is split in two paths. The first path is con-nected to the object detection and the second records and transfers the stream to the remote location. In the previous project RapTOr we used an MJPEG encoder because of the limited computational power at this moment and the unlim-ited bandwidth in the local network. Within the project RAiCe we switched to an MPEG4 encoder to transfer the high definition video stream to a remote location with limited bandwidth. After the stream is encoded, it is split again to the file recorder for playback and the sender that encrypts the data and transfers it to the remote location. The receiver forwards the decrypted stream to the video decoder that again forwards the decoded video to the display.
After the first commissioning of the redesigned system at the remote airport we had to blank out some public areas (streets, parking) for reasons of privacy. Furthermore there are some movement areas with dark asphalt (e.g. heliport). If dark objects are inside of these areas, the contrast of the captured images was not good enough for the controller to recognize them. So we had to enhance the contrast at these areas to a level where it is possible to detect these objects. Figure 2 shows on the left side the original image of the heliport with a black helicopter and on the right side the contrast enhanced image.

Figure 15: Helicopter on heliport, original (left) and enhanced (right)

To control the pan tilt zoom camera manually, we developed a display that offers several possibilities to navigate the camera. On the top right side you can find a number of preset buttons and buttons for static commands like move, zoom or clean. Below this there is a kind of wind rose. The inner circle serves as “virtual joystick” where you can seamlessly move the camera in a specified direction in a specified speed. The outer ring is to set the desired pan position. The actual position and field of view of the camera is shown there in yellow color. On the left side of the ring you find the corresponding item to set the tilt position. Outside of the ring are the fields to set the predefined zoom factors. At the bottom left there is a reduced version of the video panorama. If you click inside of this image, the camera moves to the accordingly position. The position of the camera is shown in the video panorama by a yellow frame. First trials showed that this helps orienting when users manually control the camera.

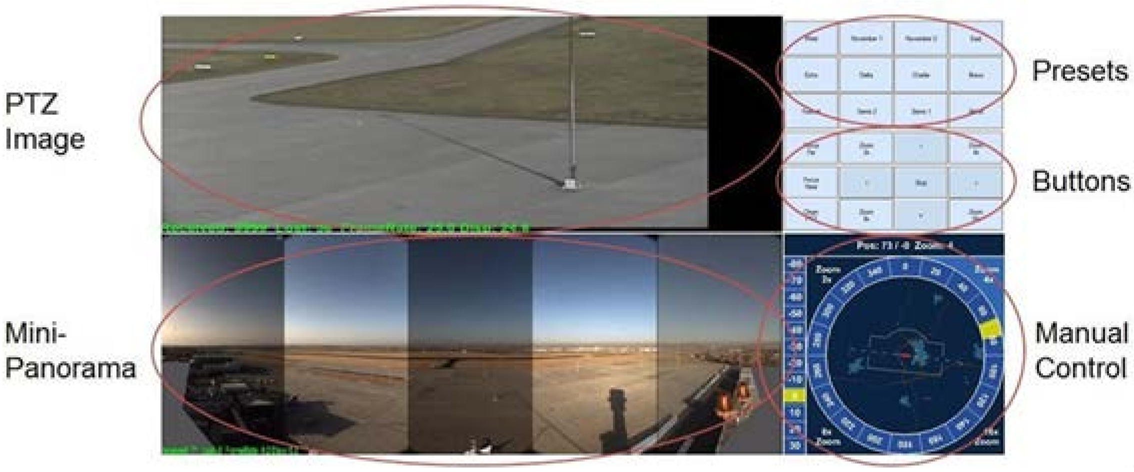


Figure 16: Pan tilt zoom camera control display

A survey of controllers showed that an automated tracking of the pan tilt zoom camera would be very helpful. Our remote tower software offers the automatic tracking of aircrafts by multilateration data and positions from the object detection. One of the next steps will be the integration of Mode-S ADSB data.

7 Image Processing and Object Tracking

Jürgen Wohlfeil, Ines Ernst and Winfried Halle

Small airports have a common characteristic in having only few of avia-tion activities per day. Control tower operators have to react in normal case only in this phase. In other time slots they have to be in a “stand by process“. In any cases of non-planned situations of aircraft flights or movements of other objects at the airport or apron the operators have also to observe the situation or have to react ade-quately. A selective marker in the images of the real time view could help the (remote) tower operator to focus the attention to mowing objects.
For this task an automatic scene analysis in form of an image data pro-cessing together with an object tracker is implemented in the virtual tower system. In the system two different image processing ap-proaches are realized with specific advantages and drawbacks; they are running in parallel Optical Flow Analysis and region tracking algorithm with background estimation. The overall result is a com-bination of both highlighted in the augmented vision.

7.1 Object detection via Optical Flow Analysis

is similar to the human peripheral vision. This approach detects objects due to their motion in a series of subsequent images. First, the corners of the image are selected as features, according to Shi and Tomasi [1994] (shown as white dots in the figure). Next, these features are tracked with the KLT-Tracker (Kanade, Lucas, Tomasi "Detection and Tracking of Point Features" [1991]) through a block of eight subsequent images. As both, feature detector and tracker have to be very sensitive in order to support the detection of small (and distant) objects as well, the majority of the features will be tracked wrong. Two techniques are used in order to disclose and erase wrongly tracked features.
First, the features are redundantly tracked back from the last image of a block back to the first image (Wohlfeil "Optical Orientation Measurement for Remote Sensing Systems with Small Auxiliary Image Sensors" [2010]). By comparing the initial and final position of a tracked feature in the first image, wrongly tracked features can be determined due to the significant (> 1 pixel) distance between these positions.

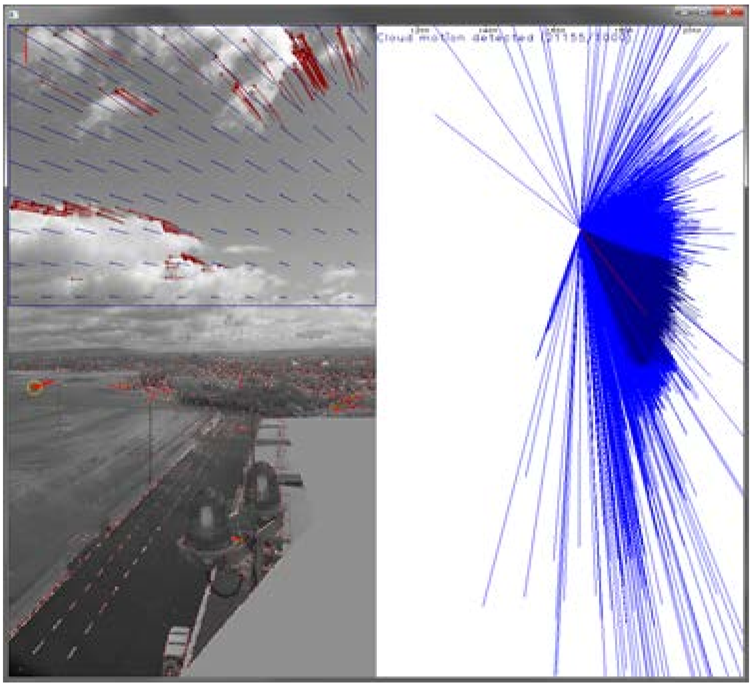


Figure 17: Example of Object tracking with optical flow (scene Erfurt airport)

Features, that move less than a pixel during the block of eight images are regarded as features from static objects and ignored (red dots in the figure). All remaining features are displayed in the figure as red crosses with a red line showing their current motion.

For the second check it is assumed the relevant objects move almost linear within the short periods of eight frames, and so their features in the images. This way more wrongly tracked and irrelevant features can be erased.
Another problem is the motion of the clouds and their shadows. They move linear and without a human understanding of the scene they have all attributes of real moving objects in the sky or on the ground, respectively. Anyway, by means of the tracked features in the sky, the mean cloud motion in object space can be determined by assuming that all clouds are in a height of 1000 meters and move in almost the same direction during several minutes. By knowing the mean cloud motion on object space, the mean cloud motion in image space is calculated (blue lines in the upper part of the figure). Features in the sky, which move the same as the clouds do, are regarded as features of clouds (dark red in the figure). Features which move in a different direction or with different speed are features of objects.
Finally, the remaining features are clustered to objects (yellow circles in the figure) and tracked through multiple blocks of images, assuming almost linear motion of the objects also during longer periods of time.

7.2 The region tracking algorithm based on background estimation

This algorithm yields many false positive candidates especially for moving clouds in the sky. On the other hand the implemented feature tracking algorithm based on optical flow doesn't give a size or form estimation for the object candidates.

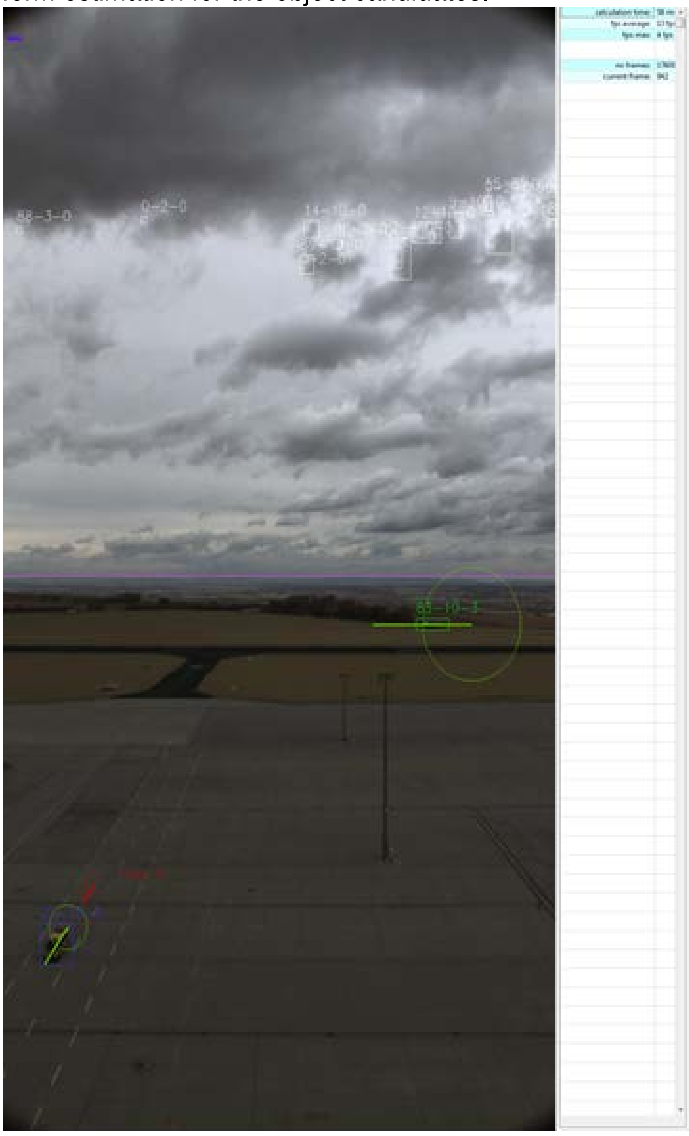


Figure 18: Combination of both algorithms (green and blue are detected objects in the image)

In the first step sufficiently reliable candidates are detected with both approaches which are then fused on the object level. Only candidates detected and tracked with both approaches in a series of subsequent images are sent as detected objects to the server system.

7.3 Classification of objects

The previous two explained algorithms have the general the task and charac-teristic to detect moving aircrafts. Especially the optical flow algorithm will lose sight of the detected mowing aircraft at once when it will stop. Also the object detection with the background estimation is not able to detect longer the tacked object. After a small period (depending on a “forgetting-factor” the object will become background itself.
Other algorithmic approaches for image interpretation of static objects, espe-cially for not moving aircrafts, are needed. For this task classification algorithms were developed. Before realizing the classification itself, it is important to find linearly independent and robust features which can separate the class “aircraft”. Also different assumptions were considered. Firstly nearly all of the aircrafts has on the surface some white shapes which are in general ho-mogenous in the grey values. Secondary, they are in general brighter than the background (soil, , grass, apron or runway. Above the horizon the effect can be the opposite; it could be the impression that they are darker than the sky as be background. For this reason each image is split between above and below the horizon was automatically calculated binary mask to uses although different algorithms for the feature generation.
Initially the total raw image was transformed in the YUV color space form the RGB image. Than a new color feature was created Feature_4= (abs(yuv_image(2,*,*)* Maske(*,*) - yuv_image(1,*,*)* Maske(*,*))) (s. also figure below)
Making the analysis more robust against the illumination variability in the images big clusters were searched which have corresponding similar grey values (these cluster are mostly the aprons surfaces or the surrounding grass; here the mean illumination can be directly detected and will normalize the classification feature.

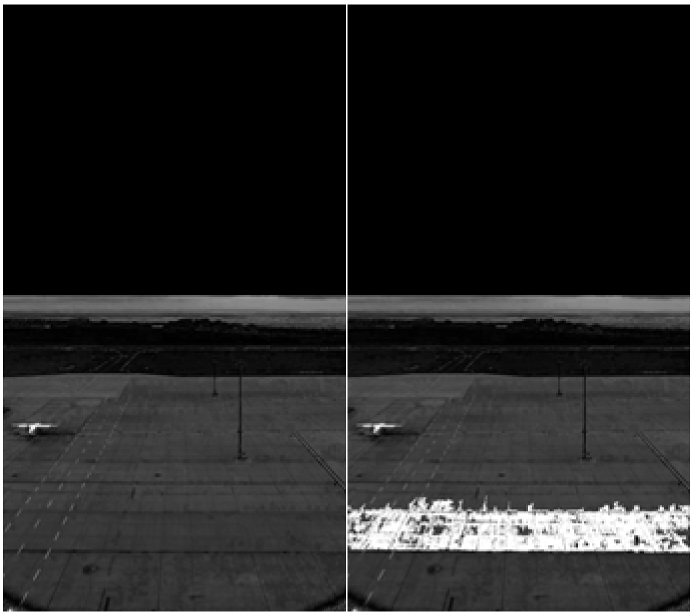


Figure 19: Further color feature (Erfurt Camera 3). Clusters for illumination normalization

Regarding the results of the classification diverse scenes were analyzed taken with different cameras of the RTO-system in Braunschweig (1600x1400 pixel camera format) and with the new system in Erfurt (HD-camera format (vertical))

Figure 20: Result-overlay (Erfurt camera 3). Result-overlay (Erfurt camera 3)

Figure 21: Further color feature (Braunschweig Cam 3). Overlay results (Braunschweig Cam 3)

8 DLR-DFS Cooperation RAiCon: Validation Experiments and Results

Maik Friedrich

This presentation describes the validation of a Remote Tower Control workplace (CWP-remote). The study shows how Air Traffic Control Officers (ATCOs) observe traffic from a traditional Controller Working Position at the airport tower (CWP-tower) in comparison to a Controller Working Position at a remote location (CWP-remote). Shadow-mode trials were used to cover perceptual, operational and human factors aspects of the validation. A re-search car was used to position static objetcs on the airfield to discriminate the detectabilty of objects with a fixed size. In addition to the static objects a DLR aircraft was used as research vehicle to fly different manouvers within the aerodrome. These manouvers allow insights on the detectablity of an aircraft within different distances from the tower and the gathering of operation information about an aircraft status. ATCOs from the Deutsche Flugsicher-ung (DFS) participating in the validation, answered questions online, synchronised on both workplaces in parallel addressing operational relevant decisions and ATCOs' perception. The results give insights on the differences between the two working positions especially the replacement of the out-the-window view with a live panoramic video reconstruction of the aerodrome, augmented by a manually controllable pan-tilt zoom camera.

Figure 22: Schematic of RTO validation experiment at Erfurt airport 7/2012

9 Remote Tower Center Simulation Environment

Sebastian Schier

The Institute of Flight Guidance operates one of the most modern simulation facilities for ATM purposes in the world. The so called “air traffic validation centre“ provides a number of advanced simulators for human in the loop trials. Out of these the Apron- and Tower Simulator (ATS) was used for the validation of the RAiCe concepts.

In general the ATS is operated by providing a close to reality working place for Apron- and Tower controllers. The simulation software “Narsim” calculates the aircraft movements and offers all necessary graphical interfaces (e.g. approach radar, weather display, etc.) to the controller. The aircraft positions are also handed over to the image generation software “ALICE” which displays the aircraft as 3D objects in a virtual world. This image is then used to show the view from the tower (or apron) control on the airfield. The interaction between controllers and the aircrafts are driven by so called pseudo pilots. These pilots are trained in ATC phraseology and aircraft operations. Within the simulations they maintain radio contact with the controller and operate the aircraft.

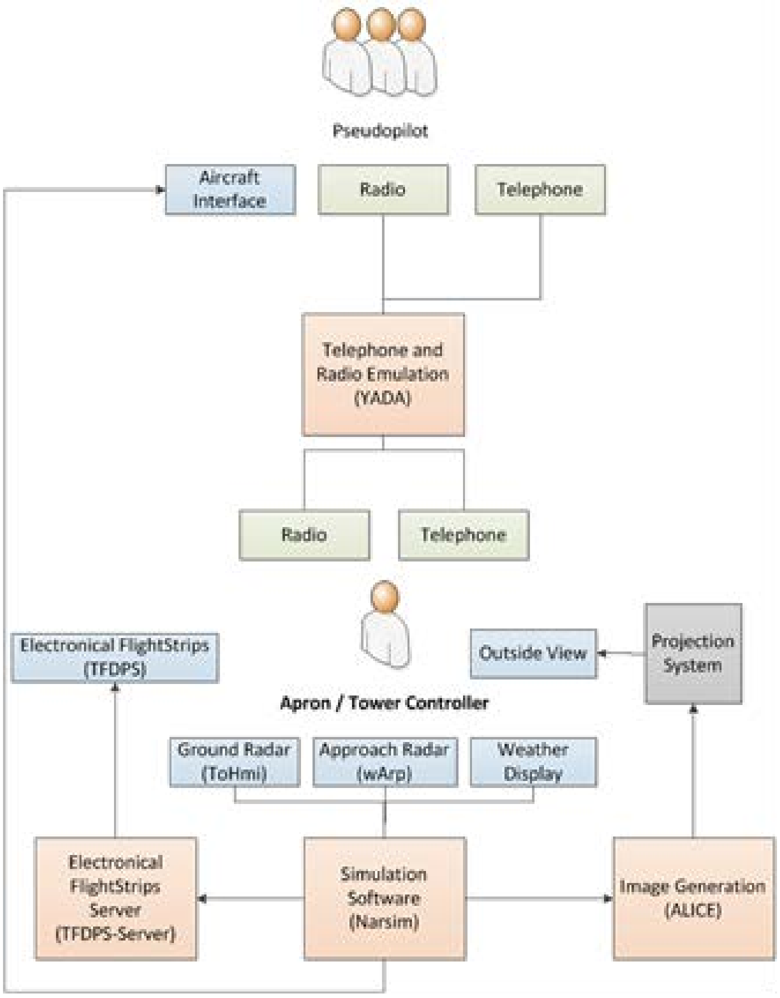


Figure 23: Schematic of Control Tower Simulator at DLR/Braunschweig

Figure 24: Remote Tower simulation setup (left console with two operators) within the Control Tower Simulator

To perform the Remote Tower trials within the project RaiCe the department of ATM-simulation had to change the hardware infrastructure of the Apron- and Tower Simulator. The RAiCe 1 trials required a remote tower working station in close connection to the Apron- and Tower Simulator. Therefore the remote tower working place designed by the department of system ergonomics was integrated into the 200° visual system of the ATS and connected to the software systems of the ATS. Within RAiCe 2 this setup was updated with a new remote tower working place, being capable of showing information for two airports.

Figure 25: Remote Tower simulation with two-airport control by two operators (executive and coordinator)

In 2010 a general revision of the Apron- and Tower Simulator had to be done. Outdated Technology, upcoming new requirements and reduction of maintenance costs caused this revision. Especially the experiences from RAiCe could be used to define requirements for the revised Apron and Tower Simulator. Thereby the so called TowerLab was designed making it possible to easily design and evaluate new tower working places. Furthermore the TowerLab is capable of simulating Remote Tower Center operations which makes it possible to take steps beyond the RAiCe objectives and to continue this research.

Figure 26: Remote Tower Center simulation within the TowerLab

10 Process Model for the Assessment of Controller Workload using FTS

Sandro Lorenz

The workload an air traffic controllers has to cope with is typically determined within a Human-Ii-the-loop real time simulation setup. Due to the fact that such simulations require a considerable amount of preparation work it might be favorable e.g. to reduce the number of potential scenarios or exercises. This selection can be supported using an appropriate Fast Time Simulation model in a preceding task. For this purpose the model of choice should be able to cover the interaction of pilot and controller to a certain extent.

In the context of the research work described here the basic FTS tool Simmod PRO! was enhanced to process aspects of air/ground communication [57].

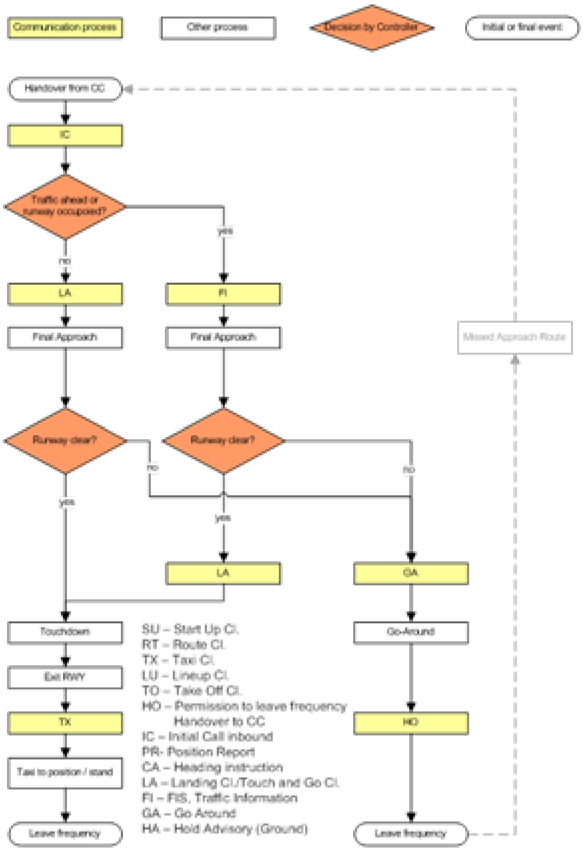


Figure 27: Exemplary process chart of the FTS model

After calibration of the model, in this case accomplished by a comparison of number and duration of chosen communication events, several traffic samples were analyzed in regard to special operational situations (e.g. simultaneous landings on local and remote airport).

Reference [57]: Walther, J. (2011): Implementierung eines Prozeßmodells zur simulativen Bewertung der Towerlotsen-Arbeitsbelastung bei zeitgleicher Ausübung von Kontrollfunktionen an zwei Flugplätzen, DLR-FL-IB 112-31

11 The Role of Workload for Work Organization in a Remote Tower Control Center*

Christoph Moehlenbrink, Anne Papenfuss and Joern Jakobi

This research focuses on the role of workload for work organization in a future remote control tower center. Currently, a tower is equipped with a controller team that maintains the declared surface movement rate under all weather conditions within the aerodrome visibility operational level (AVOL), while maintaining the required level of safety. Novel concepts consider remote control of multiple regional airports from a control center. In a simulator study at the German Aerospace Center (DLR), Institute of Flight Guidance, a remote center working environment was realized for controlling two regional airports. In a three-factor experimental design we investigated different work organizations and their effects on workload. In addition, expert observers identified safety critical ATC situations.
The results are discussed with respect to what can be learned for work organ-ization and future ATC concepts. This paper aims at better understanding the basic conditions an air traffic controller needs to meet his obligations. Such knowledge is indispensable when developing novel concepts for remote control of regional airports.

(*published in Air Traffic Control Quarterly, Vol 20, Number 1 2012)

Figure 28: Work environment: Remote Tower Center in the DLR Tower Simulator

Selected Publications (see full RaiCe publication list in section 15.3):

Moehlenbrink, C. & Papenfuss, A. (2011) ATC-Monitoring When One Controller Operates Two Airports: Research for Remote Tower Centres. HFES 2011, 19.-23. Sept. 2011, Las Vegas, Nevada.

Moehlenbrink, C., Friedrich, M. Papenfuß, A. Rudolph, M. Schmidt, M., Morlang, F. & Fürstenau, N. (2010) High-fidelity human-in-the-loop simulations as one step towards remote control of regional airports: A preliminary study. ICRAT 2010, 1.-4. Juni 2010, Budapest, Ungarn.

Moehlenbrink, C. Friedrich, M., Papenfuss, A. and Jipp M. (2011) Monitoring behaviour of tower controllers. HFES Europe Chatper, 2010, Berlin.

Lange, M., Papenfuss, A., Moehlenbrink, C. (2011) Analysis of controller-pilot communication for future concepts of remote airport control. In: Reflexionen und Visionen der Mensch-Maschine-Interaktion. Aus der Vergangenheit lernen, Zukunft gestalten, 22 (33), Seiten 525-530. VDI Verlag. 9. Berliner Werkstatt Mensch-Maschine Systeme, 05. - 07. Okt. 2011, Berlin. ISSN 1439-958X.

Lange, M., Papenfuß, A., Möhlenbrink, C. (2010) HMI Laboratory Report 4: Analysen der Towerlotsen-Piloten-Kommunikation bei gleichzeitiger Überwachung zweier Flughäfen durch einen Lotsen. DLR-Interner Bericht. DLR-IB 112-2010/40, 26 S.

12 Remote Towers: Videopanorama Frame Rate Requirements Derived from Visual Discrimination of Deceleration during Simulated Aircraft Landing**

N. Fürstenau, M. Mittendorf, S. R. Ellis[+]

In order to determine the required visual frame rate (FR) for minimizing prediction errors with out-the-window video displays at remote/virtual airport towers, thirteen active air traffic controllers viewed high dynamic fidelity simulations of landing aircraft and decided whether aircraft would stop as if to be able to make a turnoff or whether a runway excursion would be expected. The viewing conditions and simulation dynamics replicated visual rates and environments of transport aircraft landing at small commercial airports. The required frame rate was estimated from the FR-extrapolation of event probabilities conditional on predictions (stop, no-stop), and from a model fit to the perceptual discriminability A (average area under all proper ROC-curves) as dependent on FR. Decision errors are biased towards preference of overshoot and appear due to illusionary increase in speed at low frames rates. Both extrapolations yield a framerate requirement FRmin of 35 < FRmin < 40 Hz which is compared with published results [1] on shooter game scores. Definitive recommendations require further experiments with FR > 30 Hz.

Figure 29: Participant at a simulation console judging the outcome of a landing aircraft just after touchdown. Approach on the rightmost monitor, touchdown is on the left side of second monitor from the right.

Alternative Stimuli	Response for 3 Video Framerates: Probability Estimates				
	No-stop predicted			Stop predicted	
Low Deceleration No-stop Stimulus S1	p(no|S1) = C	6	0.86 (0.02)	p(yes|S1) = FA	0.14 (0.02)
		12	0.89 (0.03)		0.11 (0.03)
		24	0.94 (0.01)		0.06 (0.01)
High Deceleration Stop Stimulus S2	p(no|S2) = M	6	0.55 (0.06)	p(yes|S2) = H	0.45 (0.06)
		12	0.45 (0.05)		0.55 (0.05)
		24	0.22 (0.07)		0.78 (0.07)

Table 2: Response Matrix of landing simulation/framerate experiments: C = correct rejection, FA = false alarm, M = Misses, H = Hit rate

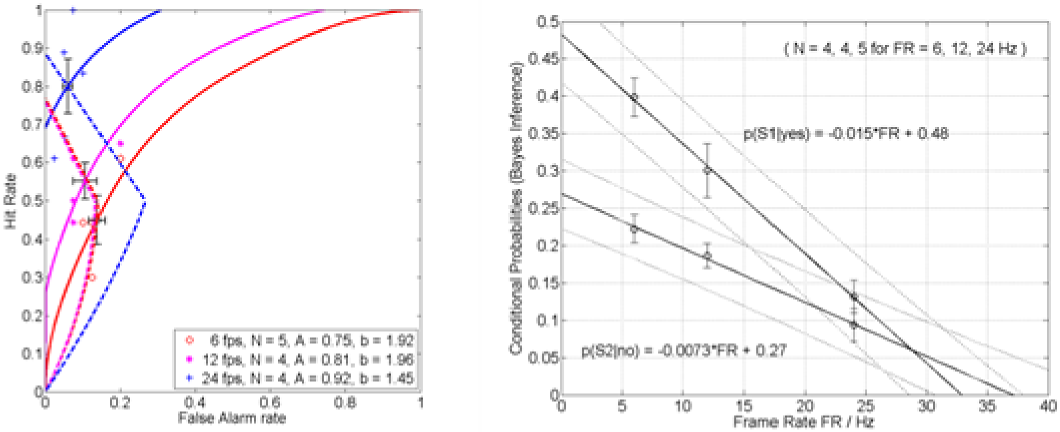


Figure 30: Left:ROC space (H, FA) with average data points for 13 subject (60 landing observations each), group averages (black crosses) for 3 different video frame rates, and corresponding isosensitivity curves (solid, parametrized by index A = average area under ROC curves) and isobias curves (decision criteria, dotted, parametrized by likelyhood ratio). Discriminability A increases with video framerate FR (maximum A = 1 = 100% : M = FA = 0).Right Figure: Bayes inference probabilities for false decision: upper probabilities with linear regression for unexpected no-stop stimulus S1 = rwy overshoot, contrary to prediction "stop"; lower probabilities with lin. Regression for unexpected stop stimulus S2, contrary to prediction no-stop. Extrapolations indicate 35 -40 video frames per second minimum for zero prediction errors under linear model.

+ Ames Res. Center, NASA
**published: Proc. SESAR Innovation Days SID2012, Braunschweig, Ed. D. Schäfer, Eurocontrol [47].

For recent publications on this topic see publications list in section 15.3.

General References (see section15.2):
[8] K. T. Claypool, and M. Claypool, “On frame rate and player performance in first person shooter games”, Multimedia Systems, 13, 2007, 3–17.

13 The Swedish approach to Remote TWR Research, Development and Implementation

Göran Lindquist (LFV)

The initial Remote TWR steps in Sweden were taken 6 years ago. The ANS management requested a live proof of concept. The driving force was the cost benefit potentials, and the large number of controlled regional airports with few daily IFR scheduled movements. A joint venture project was therefore established between LFV(ANSP) and SAAB(Industry). Contacts were taken with both DLR and DFS to exchange initial experiences in this matter.
Intensive project work during close to 3 years established a remote TWR platform in Malmö, prepared to serve the Ängelholm airport with live remote control in different shadow modes. The trials were more pragmatically- than scientifically driven. Several subject matters were involved, i.g. technical design and installations, operational methods, safety, human factors, rules & regulations, etc. All licensed controllers from this ATS participated in successful trials regarding those subject matters. The outcome identified a number of issues and areas for further development.
A number of enhanced features were also introduced in the partly parallel EU sponsored Advanced remote TWR project, with the same participating partners. Overlaid digital info, visual tracking, enhanced visual features of different kinds were tested, and became teasers for the upcoming SESAR projects.
Three other Nordic ANSP partners joined a common bid for a continued development into SESAR. Eurocontrol also joined this initiative. A more generic and common European concept view was envisaged. A joint OSED and associated functional specifications are delivered addressing both the ATC and AFIS segments. The first step is an enhanced Remote TWR application on a single airport and includes three live trials. This will be followed by multiple airport applications evaluated by a simulation and two live trials. The third step is to test the concept for Contingency purposes at larger airports.

Figure 31: LFV/Saab Remote Tower sensor system (2012)

Joint validation objectives for the three single TWR live trials have been formed. The outcome of the first two trials is very promising. 14 controllers from 5 counties participated. The visual reproduction has now reached a very satisfactory level in general. An introduction of a mature visual tracking system is a greatly welcomed enhancement to the ATCO situational awareness, as are the introduction of infrared cameras and additional hot-spot-placed cameras.
The ongoing implementation of the first live system in Sundsvall and Örnsköldsvik is challenging. Site acceptance is due this upcoming December, followed by operational validation activities in the first half of 2013. Pending the Swedish NSA approval process an operational introduction should then be executed for permanent usage onwards.

Figure 32: Saab-LFV Multiple Remote Tower Trials 2012/2013

Reference: http://www.saabgroup.com/en/Civil-security/Air-Transportation-and-Airport-Security/Air-Traffic-Management-Solutions/Remote-Tower/Features/

14 smartVISION – A new approach for video based surveillance for ATC

Michael Ellinger (Frequentis)

Using video technology as support function for Air Traffic Control Services at Airports is getting more and more popular. Most solutions are focusing on state of the art camera technology with known limitations in low light, direct sunlight or bad weather situations. The Frequentis smartVISION solution is addressing such issues by using advanced camera technologies especially designed for mission critical ground and air surveillance applications in all weather conditions, in combination with automatic detection and tracking algorithms to identify relevant objects on ground and in the air.
smartVision provides to controller with an enhanced view of the airfield and the terminal area, augmented with other relevant data such as weather and support information. A close integration with electronic flight strips and other surveillance technologies improves overall situation awareness, efficiency and increases safety. smartVision can be used in various application scenarios such as ground surveillance enhancements, contingency solutions and remoter tower deployments.

http://www.frequentis.com/en/ge/solutions-portfolio/air-traffic-management/products-and-solutions/air-traffic-control-and-automation/remote-tower-contingency-solutions [9]

15 Annex

15.1 Abbreviations

A/C	Aircraft
ADS-B	Automatic Dependent Surveillance – Broadcast for GPS-position
ASMGCS	Advanced Surface Movement Guidance and Control
CWP	controller working position
DLR	Deutsches Zentrum für Luft- und Raumfahrt (German Aerospace Centre)
GBAS	Ground Based Augmentation System
HD	High Definition (1920 x 1080 pixel Video Format)
GPS	Global Positioning System
IR	Infrared
MODE-S	Radar System with digital datalink between ground stations and A/C transponder for identification and position information, including ADS-B (GPS) broadcasts
MTF	Modulation Transfer Function
PTZ	Pan Tilt Zoom Camera
RTC	Remote Tower Center
RTO	Remote Tower Operation
SDT	Signal Detection Theory
TWR	Control Tower
ViTo	Virtual Tower
HOLACON	holographic air traffic control

15.2 Authors

Michael Ellinger (Frequentis, Austria)

Not available

Maik Friedrich (DLR) studied computer science and applied computer science at the technical colleage Schmalkalden and the university of Bamberg, Germany. He received the Master of Science from the University of Bamberg in 2008. He joined the DLR Inst. for Flight Guidance in 2008 and started within the Human Factors Department. He worked for the RTO related projects RaiCe, Victor, and RAiCon. His present research interest is in cognitive modelling of visual perception and attention.
Maik.Friedrich@dlr.de

Norbert Fürstenau (DLR) studied physics from 1971 to 1980. In 1977 he received the Diplom Physiker degree from the Inst. of Nuclear Physics of Techn. Univ. of Darmstadt and in 1981 the Dr. phil.-nat. degree from Frankfurt University for research on Laser applications in Biophysics. He joined the DLR Inst. of Flight Guidance in 1981 and after research in inertial navigation became leader of the Fiber Optic Sensors group in 1984. After re-organization of the institute in 1999 he joined the Human Factors Department together with part of the optical sensors team. He initialized the Virtual Tower (ViTo) concept study (2002–2004) after winning initial funding within the DLR “Visionary Projects competition”. He was project leader of the Remote Tower Operations project (RapTOr, 2005-2007), and the follow-up project RaiCe (Remote Airport traffic control Center, 2008-2012). In 2011 he was winner of a second prize within the fifth DLR-Visionary Projects competition (Topic: “Extreme Events Predictor”). His scientific research interest is in dynamical systems based cognitive modelling of perception, attention and decision making. He is (co-) author of 17 patents and more than 110 conference and journal papers.
norbert.fuerstenau@dlr.de

Winfried Halle (DLR) studied electronic engineering at the University of Applied Science and at the Technical University of Berlin (TU Berlin). He realised his second diploma thesis at the French School of Civil Aviation „Ecole National de L’ Aviation Civile (ENAC)“, at Toulouse, and he received his Diploma in Electronic Engineering in 1993. In 1999 he received the degree of Dr.-Ing. from the TU- Berlin. In 1994 he joined the small satellite team in the former DLR Institute of Space Sensor Technology. He was responsible for different kind of Sensor Software development and for the on board autonomy

system for the small satellite BIRD. He developed a multi spectral classification system based on artificial neural networks. For a road-traffic-analysis-project he was responsible for the real time image processing and FPGA Hardware algorithm implementation. In the Remote Tower Operations (RapTOr) project he was involved in the definition of image recognition system and in the conversion of image recognition algorithms in FPGA-Hardware. His present research interests are special satellite control aspects and sensor autonomy structures based on image recognition tasks.
winfried.halle@dlr.de

Göran Lindquist (LFV, Sweden) was trained and licensed as ATCO in LFV/Sweden. Main duty initially as Air Traffic Controller at Malmö ACC and Approach, 10 years. Later also licensed for temporary military TWR. ATS expert at LFV headquarter, 4 years. Instructor and Course headmaster at Swedish ATS Academy(SATSA), 9 years. ICAO employment as Senior ATC Instructor in the Middle east/Jeddah, >2 years. Head of LFV ATC-development & Simulation Dept. at SATSA, 7 years. 5 years head of Training for the Swedish and International training at the same institute. Remote TWR project manager and focal point in LFV since 2006.
Goran.lindquist@lfv.se

Sandro Lorenz (DLR) graduated in Transportation Engineering at the Dresden University of Technology (TU Dresden) in 1999. Since then he has been working as a research associate at the DLR Institute of Flight Guidance in the field of air traffic performance assessment focussed on the use of Fast Time Simulation models.
sandro.lorenz@dlr.de

Christoph Möhlenbrink (DLR) studied psychology at the University of Konstanz, Germany and received the Diplom Psychologe degree in 2005 with a magnetoencephalograpy study on word processing of visual stimuli. Since 2006 he was pursuing PhD research in the field of cognitive modelling of decision processes at the DLR Institute of Flight Guidance. He received his Dr.-Ing. Degree from the faculty of Mechanical Engineering in 2011.
christoph.moehlenbrink@dlr.de

Anne Papenfuß (DLR) holds a Magistra Artium in Media Sciences from the Technical University Braunschweig & University of Arts Braunschweig, Germany. Since 2008 she works at the Human Factors department of the Institute of Flight Guidance in the fields of concept development and validation, with a focus on collaborative work and teamwork. Within the project RAiCe she was responsible for the concepts of work organization in a future remote tower center. She was involved in the planning and organisation of a series of real-time high-fidelity simulations with DFS controllers within the internal project, in order to develop operational requirements for remote tower centre control with a special focus on workload management and team work organisation. Her research interest is in the analysis of team communication to assess team situation awareness.
anne.papenfuss@dlr.de

Michael Rudolph (DLR) was educated as Mathematical Assistant at Airbus Industries in Bremen and studied Informatics at the Technical University of Braunschweig. After receiving the Diplom Informatiker degree in 2002, he joined the Human Factors Department of the Inst. of Flight Guidance in the same year. Presently he is responsible for the realization of the video panorama and augmented vision software of the RTO experimental system.
michael.rudolph@dlr.de

Sebastian Schier (DLR) studied computer science at the Technical Univ. of Braunschweig and received the master degree in 2010. He joined the DLR in 2004 working as a software developer parallel to his studies. From 2004 to 2007 Sebastian worked at the Institute of Flight Systems within the Simulation department. Here he supported the software development of the experimental aircraft ATTAS. Afterwards Sebastian changed to the Institute of Flight Guidance, where he is responsible for the Apron- and Tower Simulator(ATS). As the ATS was one of the main facilities to evaluate RAiCe concepts, Sebastian was in charge to design the simulations, prepare the simulator, conduct the exercise and analyse the data in the aftermath.
Sebastian.schier@dlr.de

Markus Schmidt (DLR) studied mechanical engineering / micromechanics at the Technical Univ. of Braunschweig and received the Diplom Ingenieur degree in 1998 with a work in fiber – optic sensor technology. In the same year he joined the sensor technology group of the DLR Inst. for Flight Guidance where he was involved in the development of microinterferometer strain gauges and phase demodulation systems for sensor readout. Together with his co-authors he joined the human factors department in 2000 where he focused on research in new HMI technologies and was involved in the Virtual Tower concept study (2002 – 2004) and in the first internal RTO project RapTOr. He is presently deputy project leader of the RAiCe project and in the context of the DLR-DFS cooperation RAiCon responsible for the implementation of the RTO experimental system in Erfurt. His research interest is in the system aspects of high resolution video and projection technologies and data fusion.
markus.schmidt@dlr.de

15.3 General References

[1] Schmidt-Ott, J.R., Ellis, S.R., Adelstein, B.D., Krozel, J., Reisman, R.J., Gips, J. (2002): Augmented Reality in a Simulated Tower Environment: Effect of Field of View on Aircraft Detection. NASA/TM-2002-211853

[2] Ellis, S.R. (2006): Towards Determination of Visual Requirements for Augmented Reality Displays and Virtual Environments for the Airport Tower. Proc. NATO workshop on Virtual Media for the Military. HFM-121/RTG 042 HFM-136, West Point,/NJ

[3] Brinton & Atkins (2006): *Remote Airport Traffic Services Concept,* Proceedings, I-CNS Conf., Baltimore 5/2006

[4] Hannon, D., Lee, J. T, . Geyer, M., Sheridan, T., Francis, M., Woods, S., Malonson, M. (2008): “Fea-sibility evaluation of a staffed virtual tower". The Journal of Air Traffic Control, Winter 2008, 27-39.

[5] Ellis, S. R. and Liston, D. B. (2010). *Visual features involving motion seen from airport control towers.* Proc.11th IFAC/-IFIP/IFORS/IEA Symposium. on Analysis, Design, and Evaluation of Human-Machine Systems 9/31-10/3, 2010, Valenciennes, France

[6] Ellis, S. R. and Liston, D. B. (2011). *Static and motion-based visual features used by airport tower controllers.* NASA TM-2011-216427, Ames Research Center, Moffett Field, CA

[7] Watson, A.B, Ramirez, C.V., Salud, E., (2009): “Predicting visibility of aircraft”, PLoS ONE. 4(5): e5594. Published online 2009 May 20. doi: 10.1371/journal.pone.0005594

[8] Claypool, K. T., Claypool, M (2007): “On frame rate and player performance in first person shooter games”, Multimedia Systems, 13, 3–17.

[9] http://www.frequentis.com/en/ge/solutions-portfolio/air-traffic-management/products-and-solutions/air-traffic-control-and-automation/remote-tower-contingency-solutions

15.4 Publications: Remote Tower Team (2002 – 2012)

[1] Fürstenau, N. (2002): *Nonlinear Dynamics of Belief Updating and Decision Making*, Proc. IEEE Conf. Systems, Man and Cybernetics, Hammamet / Tunesia (2002). IEEE Cat. no. 02CH37349C, ISBN 0-7803-7438-X, paper TP 1O2

[2] Fürstenau, N. (2002): *Nichtlineare Dynamik der Hypothesenbildung,* DGLR-Bericht 2002-04: "Situation Awareness in der Fahrzeug – und Prozeßführung", ISBN3-932182-29-4, Deutsche Gesellschaft für Luft-und Raumfahrt, Hrsg.: M. Grandt, K.-P. Gärtner, (2002), 199 – 216

[3] Fürstenau, N. (2003): *A nonlinear dynamics model of binocular rivalry*, in: "The Logic of Cognitive Systems", Proc. 5th Int. Conf. Cognitive Modeling ICCM 2003, Hrsg.: F. Detje, D. Dörner, H. Schaub, Bamberg 10.-12.4.03, pp. 111-116

[4] Fürstenau, N. (2003): *Virtual Reality for Integration,* Proc. 12th Scientific Seminar: The Challenges of Integration", DLR, Inst. of Flight Guidance, 30.-31.Oct. 2002, in: Editor H. Hartmann (DLR), DLR-Mitteilung 3-2003

[5] Fürstenau, N. (2003): *A nonlinear dynamics model of binocular rivalry and cognitive multistability,* Proc. IEEE-SMC 2003, IEEE Int. Conf. Systems, Man, and Cybernetics, Washington/DC, (2003), ISBN 0-7803-7953-5, IEEE Cat. no. 03CH37483C, pp. 1081-1088

[6] Fürstenau, N., Rudolph, M., Schmidt, M., Lorenz, B., Albrecht, T. (2004): *On the use of transparent rear projection screens to reduce head – down time in the air – traffic control tower*, Proc. Human Performance, Situation Awareness and Automation Technology (HAPSA II) 22. - 25.3.04, Daytona Beach / Fl, Lawrence Erlbaum Publishers Inc. (2004), 195 – 200

[7] Fürstenau, N. (2004): *A recursive attention – perception chaotic attractor model of cognitive multistability,* Proc. 6th Int. Conf. on Cognitive Modeling (ICCM 2004), Pittsburg/PA July 30 – Aug.1 (2004), M. Lovett, C. Schunn, C. Lebiere, P. Munro, Editors. Lawrence Erlbaum Associates Publishers, Mahwah/NJ (2004), 348 – 349

[8] Fürstenau, N. (2004): *A chaotic attractor model of cognitive multistability, Proceedings of the IEEE 2004 Int. Conf. on Systems, Man and Cybernetics,* ISBN 0-7803-8567-5, IEEE cat. no. 04CH37583C. pp. 853-859

[9] Fürstenau, N., Rudolph, M., Schmidt, M., Werther, B. (2004): *Virtual Tower*, in: " Wettbewerb der Visionen 2001 – 2004", Hrsg. Deutsches Zentrum für Luft-und Raumfahrt (2004) pp.16 – 21

[10] Fürstenau, N. (2005): *Nonlinear Dynamics Model and Simulation of Spontaneous Perception Switching with Ambiguous Visual Stimuli,* Proceedings Conf. Human Computer Interaction 2005: Augmented Cognition I, Las Vegas 22.7. – 27.7. 2005, vol. 11: Foundations of Augmented Cognition, paper 109

[11] Fürstenau, N. (2005): *Virtual Tower*, 5th ATM R&D Symposium (DLR, Eurocontrol, EC), Braunschweig, 11.-13.10. 2005, http://atmsymposium.dlr.de

[12] Fürstenau, N. (2005): *Modellierung und Simulation spontaner Wahrnehmungswechsel bei mehrdeutigen Stimuli in Augmented Vision Systemen*, 6. Berliner Werkstatt Mensch-Maschine-Systeme 13.-15.10. 2005, in: VDI – Fortschrittsberichte Reihe 22: Zustandserkennung und Systemgestaltung, ZMMS Spektrum Bd. 19, VDI-Verlag Düsseldorf (2005) 119-124

[13] Werther, B., Schnieder, E. (2005): Formal Cognitive Resource Model: Modeling of human behavior in complex work environments, in: *Proc. Int. Conf. Computational Intelligence for Modelling, Control & Automation (CIMCA 2005),* Wien: 2005, pp. 606 – 611.

[14] Werther, B. (2006): Colored Petri net based modeling of airport control processes. In: Proc. Int. Conf. Comput. Intelligence for Modelling, Control & Automation (CIMCA) Sydney (2006) IEEE ISBN 0-7695-2731-0

[15] Fürstenau, N. (2006): Modelling and Simulation of spontaneous perception switching with ambiguous visual stimuli in augmented vision systems. E. André et.al. (eds.): Perception and Interactive Technologies PIT 2006, Lecture Notes in Artificial Intelligence vol4021, Springer, Berlin, New York, (2006) pp.20-31

[16] Schmidt, M., Rudolph, M., Werther.B, Fürstenau.N (2006): Remote Airport Tower operation with Augmented Vision Video Panorama HMI, Proc. 2nd Int. Conf. Res. in Air Transportation (ICRAT 2006), Belgrade (2006), pp. 221-229

[17] Schmidt, M., Rudolph, M, Werther, B., Fürstenau, N. (2007): Development of an Augmented Vision Videopanorama Human-Machine Interface for Remote Airport Tower Operation, Proc. HCII2007 Beijing, Springer Lecture Notes Computer Science 4558 (2007) 1119-1128

[18] Fürstenau, N., Mittendorf, M. (2007): Simulation of Spontaneous Perception Switching with a Nonlinear Dynamics Model using Perception-Attention-Memory Coupling, HCII2007 Beijing, Poster

[19] Fürstenau, N. (2007): A Computational Model of Bistable Perception-Attention Dynamics with Long Range Correlations, Proc. 30th German Conf. on Artificial Intelligence (KI2007), in: J. Hertzberg, M. Beetz, R. Englert (Eds.): Lecture Notes in Artificial Intelligence (LNAI), Springer 2007, pp. 251-263

[20] Fürstenau, N., Mittendorf, M. (2007): Simulation of Bistable Perception with Long Range Correlations Using Perception-Attention-Memory Coupling, Proc (Abstract). 14th Fall Academy "Theory in Cognitive Neuroscience", Wildbad Kreuth 4.-7.11.07, (2007), 12

[21] Fürstenau, N., Schmidt, M., Rudolph, M., Möhlenbrink, C., Werther, C. (2007): Augmented Vision Videopanorama System for Remote Tower Operation: Initial Validation, Proc. 6th Eurocontrol Innovative Research Workshop, Bretigny, 4.-6. 12. 2007, 125-132

[22] Werther, B., Moehlenbrink, C., Rudolph, M. (2007): Colored Petri Net based Formal Airport Control Model for simulation and analysis of airport control processes, Proc. HCII 2007, Beijing, Springer Lecture Notes in Computer Science, vol. 4558

[23] Möhlenbrink, C., Werther, B., Rudolph, M. (2007):FAirControl: Ein Werkzeug zur Modellierung und Ana-lyse von Verhaltensweisen am Lotsenarbeitsplatz. Proc. BWMMS 2007, Berlin, veröfffentlicht in Fortschritt Berichte VDI Reihe 22 (ZMMS Spektrum) Nr. 24

[24] Fürstenau, N. (2008): Simulation of bistable perception with long range correlations using reentrant nonlinear perception-attention-memory coupling. Proc. (Abstracts) 12th Annual Meeting, Association for the Scientific Study of Consciousness, Taipei, 19.-22. 6. 2008, p. 75-76

[25] Fürstenau, N., Schmidt, M., Rudolph, M., Möhlenbrink, C., Halle, W. (2008): *Augmented vision videopanorama system for remote airport tower operation,* Proc. ICAS 2008, 26th Int. Congress of the Aeronautical Sciences.I. Grant (Ed.), Anchorage, Sept. 14-19 2008, ISBN 0-9533991-9-2

[26] Fürstenau, N., Mittendorf, M. (2008): Nonlinear dynamics model for simulation of multistable perception using reentrant perception-attention-memory coupling. Proc. (Abstracts) KogWis 2008, 9. Jahrestagung Gesellschaft für Kognitionswissenschaften, Dresden 28.9.-1.10.2008, p. 57

[27] Fürstenau, N., Schmidt, M., Rudolph, M., Möhlenbrink, C., Papenfuß, A., Kaltenhäuser, S. (2009): *Steps towards the Virtual Tower: Remote Airport Traffic Control Center (RAiCe),* Proc. EIWAC 2009, ENRI Int. Workshop on ATM & CNS, Tokyo, 5.-6.3.2009, pp. 67-76

[28] Schmidt, M., Rudolph, M., Papenfuß, A., Friedrich, M., Möhlenbrink, C., Kaltenhäuser, S., Fürstenau, N. (2009): Remote airport traffic control center with augmented vision videopanorama. In: *Proc. 28th IEEE-DASC 2009*, Orlando, pp. 4.E.2-1 – 4.E.2-15

[29] Fürstenau, N., Schmidt, M., Rudolph, M., Möhlenbrink, C., Papenfuß, A., Kaltenhäuser, S. (2009): *Remote Airport Traffic Control Center,* Proc. ICNS 2009 Conference, Arlington/VA 13.-15.5.09

[30] Fürstenau, N. (2009): Computational nonlinear dynamics model of percept switching with ambiguous stimuli. In.: V.G. Duffy: Digital human modeling. HCII 2009, Lecture notes in computer science. LNCS vol. 5620 (2009) pp. 227-236

[31] Fürstenau, N., Schmidt, M., Rudolph, M., Möhlenbrink, C., Kaltenhäuser, S., Schlüßler, E. (2010): Experimental System for Remote Airport Traffic Control Center Research. Proceedings IFAC-HMI, papers online, paper 22, available: www.ifac-papersonline.net/detailed/47051.html

[32] Fürstenau, N. (2010): *Self Oscillator Model of bistable perception explains reversal rate characteristic of interrupted ambiguous stimulus*, Proc. 10th Biannual Meeting of German Kogn..Science Soc (KogWis 2010), Ed. J. Haag et.al., Potsdam Kogn. Science Series, vol.2, Univ.-Verlag Potsdam (2010) p. 104

[33] Fürstenau, N. (2010): *A nonlinear dynamics model for simulating long range correlations of cognitive bistability.* Biological Cybernetics 103, (2010) 175-198, DOI 10.1007/s00422-010-0388-4;

[34] Moehlenbrink, C., Friedrich, M., Papenfuß, A., Rudolph, M., Schmidt, M., Morlang, F. and Fürstenau, N. (2010) *High-fidelity human-in-the-loop simulations as one step towards remote control of regional airports: A preliminary study.* ICRAT 2010, 1.-4. Juni 2010, Budapest, Ungarn.

[35] Moehlenbrink, C., Friedrich, M., Papenfuss, A. and Jipp, M. (2010): *Monitoring behaviour of tower controllers.* HFES Europe Chapter, 2010, Berlin.

[36] Papenfuß, A., Friedrich, M., Möhlenbrink, C., Rudolph, M., Schier, S., Schmidt, M. und Fürstenau, N. (2010): *High-fidelity Tower Simulation for operational validity of Remote Tower Control.* 11th IFAC/IFIP/IFORS/IEA Symposium on Analysis, Design and Evaluation of Human-Machine Systems, 31.Aug. - 03.Sept.2010, Valenciennes.

[37] Fürstenau, N. (2011): *Self-Oscillator Model of Bistable Perception with Interrupted Ambiguous Stimulus Explains Percept Stabilization and Reversal Rate Characteristics*, Proc. ASSC 15, Kyoto 9.-12.6.2011, Ed. T. Matsuzawa, Kyoto University, p. 70

[38] Ellis, S., Fürstenau, N. and Mittendorf, M. (2011): *Frame Rate Effects on Visual Discrimination of Landing Aircraft Deceleration: Implications for Virtual Tower Design and Speed Perception.* Proceedings of the Human Factors and Ergonomics Society 55th Annual Meeting, Sept. 19-23, 2011, Las Vegas, NV USA, pp. 71-75.

[39] Moehlenbrink, C. and Papenfuss, A. (2011) *ATC-Monitoring When One Controller Operates Two Airports: Research for Remote Tower Centres.* HFES 2011, 19.-23. Sept. 2011, Las Vegas, Nevada

[40] Ellis, S., Fürstenau, N. and Mittendorf, M. (2011): *Determination of Frame Rate Requirements of Video-panorama-based Virtual Towers using Visual Discrimination of Landing Aircraft Deceleration during simulated Aircraft Landing.* Fortschritt-Berichte VDI, Reihe 22, No. 33, pp.519-524

[41] Lange, M., Papenfuss, A., Moehlenbrink, C. (2011): *Analysis of controller-pilot communication for future concepts of remote airport control.* In: Reflexionen und Visionen der Mensch-Maschine-Interaktion. Aus der Vergangenheit lernen, Zukunft gestalten, 22 (33), Seiten 525-530. VDI Verlag. 9. Berliner Werkstatt Mensch-Maschine Systeme, 05. - 07. Okt. 2011, Berlin. ISSN 1439-958X.

[42] Papenfuss, A. und Moehlenbrink, C. (2011): *The opportunities and challenges of team work in remote tower center operations.* 9. Berliner Werkstatt Mensch-Maschine-Systeme, 05.-07. Okt. 2011, Berlin.

[43] Fürstenau, N. (2012): Percept choice dynamics of stochastic self-oscillator model explains bistable perception under interrupted ambiguous stimulus, Biological Cybernetics,submitted 2012, Manuscript # BICY-D-12-00058, revised version under work

[44] Möhlenbrink, C., Papenfuß, A., Jakobi, J. (2012): The role of workload for work organisation in a remote tower control center. Proc. ATM 2011. Published in: ATC Quarterly, Spec. Issue ATM-2011, vol.20, no. 1, pp.5-26

[45] Fürstenau, N. (2012): *Self-oscillator model of cognitive bistability explains percept reversal rate characteristics with periodically interrupted ambiguous stimulus*. Poster, Summer School in Cognitive Science, Montreal 30.6.-12.8. 2012

[46] Fürstenau, N. (2012): *Percept choice dynamics of stochastic self-oscillator model dominates percept reversal rate charactereistics under periodically interrupted ambiguous stimulus*, Proc. 11th Meeting of German Kognitive Science Society, KOGWIS 2012, Ed. U. Schmid et.al., Univ. of Bamberg Press, p. 82-83

[47] Fürstenau, N., Mittendorf, M., Ellis, S. (2012): *Remote Towers: Videopanorama Frame Rate Requirements derived from Visual Discrimination of Deceleration during Simulated Aircraft*

Landing. Proceedings 2nd SESAR Innovation Days, Braunschweig 2012, online: http://www.sesarinnovationdays.eu/2012/papers

[48] Fürstenau, N., Friedrich, M., Mittendorf, Schmidt, M., Rudolph, M. (2013). *Discriminability of Flight Maneuvers and Risk of False Decisions Derived from Dual Choice Decision Errors in a Videopanorama-Based Remote Tower Work Position*. Proc. HCI 2013 – Engineering Psychology and Cognitive Ergonomics, D. Harris (Ed.), Springer Lecture Notes Computer Science, in print

Bachelor-, Master-, Diploma- Thesis. Internal Reports (DLR-IB)

[49] Papenfuß, A. und Möhlenbrink, C. (2009): *Kognitive Arbeitsanalyse Lotsenarbeitsplatz.* Internal Report. DLR-IB 112-2009/20, 59 S.

[50] Möhlenbrink, C., Papenfuß, A. (2009), N. Schneider, F. Morlang: *Ergebnisse der ersten RAiCe-Simulationskampagne 1a*, Interner Bericht IB 112-2009/36

[51] Möhlenbrink, C., Friedrich, M., Papenfuß, A., Aust, F., Jipp, M. (2009): *Monitoring Behavior of Tower Controllers,* Interner Bericht DLR-IB-112-2009/42

[52] Beltran, M. (2010): C++ - Processing of Mode-S, Multilateration, and ADS-B Position Data. DLR-FL-IB 112-2010/33. In fulfillment of the Diploma Thesis, Univ. Escola Politecnica Superior de Castelldefels

[53] Lange, M., Papenfuß, A. and Möhlenbrink, C. (2010): *Analysen der Towerlotsen-Piloten-Kommunikation bei gleichzeitiger Überwachung zweier Flughäfen durch einen Lotsen.* DLR-Interner Bericht. DLR-IB 112-2010/40, 26 S.

[54] Möhlenbrink ,C., Papenfuß, A. (2010): *Ergebnisse der ersten RAiCe-Simulationskampagne 1b*, Interner Bericht IB 112-2010/55

[55] Lange, M., Papenfuß, A. and Möhlenbrink, C. (2011): *Analysen des Zusammenhangs zwischen dem Workload von Towerlotsen und objektiven Arbeitsparametern.* DLR-Interner Bericht. DLR-IB 112-2011/46, 26 S.

[56] Papenfuß, A. und Möhlenbrink, C. (2011): *"Betrachtung eines Konzeptes zur Fernüberwachung von Flughäfen: Welche Rolle spielt Teamarbeit"*. DLR-Interner Bericht. DLR IB 112-2011/01. 46 S.

[57] Walther, J. (2011): *Implementierung eines Prozeßmodells zur simulativen Bewertung der Towerlotsen-Arbeitsbelastung bei zeitgleicher Ausübung von Kontrollfunktionen an zwei Flugplätzen,* DLR-FL-IB 112-31

[58] Mehta, V. (2011): Automatic Detection of Aircraft using Visual Cues and Prediction of the Stop Time after Touchdown. Master Thesis, Hochschule Darmstadt, Univ. of Applied Sciences

[59] Peters, M. (2012): *Analysis of Critical Situations at Remote Tower Operated Airports.* DLR-Interner Bericht. DLR-IB. 67S.

[60] Mahmoudzadeh Vaziri, G., Fürstenau, N. (2013): Modulationsübertragungsfunktion (MTF) der Panoramakameras. Interner Bericht DLR-IB 112-2013/9, pp. 1-67

RTO Workshops, Special sessions / sessions chaired by DLR

[61] 1st Int. Scientific Remote Tower Workshop, (DLR-Braunschweig), Projekt RApTOr, 27.9. 2006

[62] 2nd Int. Scientific Remote Tower Workshop, (DLR-Braunschweig), Projekt RApTOr , 8. - 9.4. 2008

[63] 11th IFAC-HMI Valenciennes, (31.8.-3.9.2010): Virtual Tower sessions 1, 2: 8 papers, published IFAC-online: www.ifac-papersonline.net/detailed/47051.html

[64] BWMMS, Berlin (5.-7.10.2011): Special Sessions 3a, 3b: Steps towards the Remote Tower Center: 6 papers , published: Fortschritt-Berichte VDI, Reihe 22, No. 33

[65] 3rd Int. Scientific Remote Tower Workshop, (DLR-Braunschweig), Projekt RAiCe, 30.11.2012. published as: Internal Report DLR IB-112-2013/20

Patents

[66] Fürstenau, N., Rudolph, M., Schmidt, M., Werther, B., Hetzheim, H., Halle, W., Tuchscheerer, W. (2005):Flugverkehr-Leiteinrichtung (Virtueller Tower), Deutsche Patentanmeldung Nr. 10 2005 055 879.8, 23.11.2005, Offenlegungsschrift DE 10 2005 055 879 A1 2007.05.31; Europäische Patentanmeldung Nr. 06 021 305.5-2215, erteilt EP 1791364 12/2008

[67] Fürstenau, N., Rudolph, M., Schmidt, M., Werther, B. (2006): Flughafenverkehrsinformations-Anzeigesystem (airport traffic information display system), eingereicht 20.3.2006: AP67/106, Deutsche Patentanmeldung Nr. 10 2006 060 904.2,

[68] Fürstenau, N., Werther, B., Schmidt, M., Rudolph, M. (2007): *Automatisierungssystem für den Flughafenbodenverkehr mittels Petri-Netz-Steuerung*, German Patent appl. (2007), no. 102007043025

15.5 List of Figures

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15.7 Participants

Name		Company	Contact
Bork	Christian	The Tower Company	Christian.bork@the-tower-company.de
Brunner, Dr.	Brigitte	DLR	brigitte.brunner@dlr.de
Carstengerdes, Dr.	Nils	DLR	Nils.carstengerdes@dlr.de
De Meerleer	Peter	BARCO / Belgium	Peter.demeerleer@barco.com
Edlmair	Reinhard	Vienna Univ. Econom. / Austria	reinhard.edlmair@wu-wien.ac.at
Eisele	Michael	BARCO	Michael.eisele@barco.com
Ellinger	Michael	Frequentis / Austria	Michael.ellinger@frequentis.com
Fält	Kari	Saab / Sweden	kari.falt@saabgroup.com
Fietz	Hans-Jörg	LwFüKdo	HansJoergFietz@bundeswehr.org
Friedrich	Maik	DLR	Maik.friedrich@dlr.de
Fürstenau, Dr.	Norbert	DLR	Norbert.Fuerstenau@dlr.de
Gerndt, Dr.	Andreas	DLR	Andreas.gerndt@dlr.de
Ghourani	Fadi	Searidge / Canada	fadi@searidgetech.com
Halle, Dr.	Winfried	DLR	Winfried.Halle@dlr.de
Haupt	Ricarda	DFS	Ricarda.haupt@dfs.de
Heeb	Thorsten	DFS	Thorsten.heeb@dfs.de
Helms	Marcus	DLR	Marcus.Helms@dlr.de
Henriksson	Mikael	LFV / Sweden	mikael.henriksson@lfv.se
Inoue, Dr.	Satoru	ENRI / Japan	s-inoue@enri.go.jp
Jakobi	Jörn	DLR	joern.jakobi@dlr.de
Kügler, Dr.	Dirk	DLR	Dirk.kuegler@dlr.de
Leitner	Rodney	HFC	Rodney.leitner@human-factors-consult.de
Lindqvist	Göran	LFV / Sweden	goran.lindqvist@lfv.se
Lorenz	Sandro	DLR	sandro.lorenz@dlr.de
Mahmoudzadeh Vaziri	Ghazal	DLR	Ghazal.mahmoudzadehvaziri@dlr.de
Mattaei	Udo	BAAINBw	UdoMatthaei@bundeswehr.org
Mittendorf	Monika	DLR	Monika.Mittendorf@dlr.de
Moehlenbrink, Dr.	Christoph	DLR	christoph.möhlenbrink@dlr.de
Papenfuß	Anne	DLR	Anne.Papenfuss@dlr.de
Purvin	Bernd	ATCO	Bernd.purvin@live.de
Radüntz	Thea	BAUA	Raduentz.thea@baua.bund.de
Rudolph	Michael	DLR	michael.rudolph@dlr.de
Schier	Sebastian	DLR	Sebastian.schier@dlr.de
Schindler	Tristan	DLR	Tristan.schindler@dlr.de
Schmidt	Markus	DLR	markus.schmidt@dlr.de
Thurow	Christian	Searidge / Canada	christiant@searidgetech.com
Walther	Jan	airsight	j.walther@airsight.de
Wittbrodt, Dr.	Nora	Fraport	n.wittbrodt@googlemail.com
Zimmermann	Winfried	Cassidian	Winfried.zimmermann@cassidian.com